

AN EXPLORATION OF ENVIRONMENTAL  
TECHNOLOGY TRANSITION FROM THE  
LABORATORY TO THE FIELD

THESIS

Michael A. Greiner, Captain, USAF

AFIT/GCA/LAS/96S-7

DEPARTMENT OF THE AIR FORCE  
AIR UNIVERSITY  
**AIR FORCE INSTITUTE OF TECHNOLOGY**

DTIC QUALITY INSPECTED 3

Wright-Patterson Air Force Base, Ohio

AFIT/GCA/LAS/96S-7

AN EXPLORATION OF ENVIRONMENTAL  
TECHNOLOGY TRANSITION FROM THE  
LABORATORY TO THE FIELD

THESIS

Michael A. Greiner, Captain, USAF

AFIT/GCA/LAS/96S-7

Approved for public release; distribution unlimited

19970108 110 DTIC QUALITY INSPECTED 3

The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

AFIT/GCA/LAS/96S-7

AN EXPLORATION OF ENVIRONMENTAL TECHNOLOGY  
TRANSITION FROM THE LABORATORY TO THE FIELD

THESIS

Presented to the Faculty of the Graduate School of

Logistics and Acquisition Management of the

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Cost Analysis

Michael A. Greiner, B.S.

Captain, USAF

September 1996

Approved for public release; distribution unlimited



### Acknowledgments

I am sincerely grateful to Major Richard M. Franza for his guidance in completing this research effort. His insight into the transition of technology, along with his interest in seeing to it that I experienced the thesis process to its fullest extent, has made for a research experience that I will surely benefit from for years to come. He provided motivation to explore and learn, fostering an environment that encouraged me to express my ideas in the design of this thesis. I would also like to thank Lieutenant Colonel Steven T. Lofgren for his guidance in keeping this research focused on the environmental issues facing the Air Force today.

The quality of this research effort was greatly enhanced by the efforts of Armstrong Laboratory, Environics Directorate, and Wright Laboratory. Specifically, I would like to thank Mr. Dick Woodworth of Armstrong Laboratory and Mr. Jack Sperry of Wright Laboratory for their tireless efforts in helping me identify potential environmental technology transition cases. I owe a second thanks to Mr. Woodworth for his efforts in coordinating a data gathering trip that proved crucial to the success of this thesis.

Finally, I would like to thank my wife and son, Malinda and Andrew, who provided motivation and encouragement throughout the entire thesis process. I am forever indebted to them for their unwavering support of my goals and hopes for this research effort.

Michael A. Greiner

## Table of Contents

	Page
Acknowledgments .....	ii
List of Figures .....	vi
List of Tables.....	vii
Abstract.....	viii
I. Introduction .....	1
Background .....	1
Department of Defense Implications.....	2
Definition of Terms.....	4
Research Objectives.....	5
Scope of Research .....	6
Thesis Overview .....	6
II. Literature Review .....	8
Overview .....	8
Environmental Legislation.....	8
GAO Findings.....	10
Weapon System Acquisition.....	12
Technology Transition .....	14
Barriers.....	15
Technical Barriers .....	15
Regulatory Barriers .....	16
People Barriers .....	17
Bridges.....	21
Case Studies .....	24
Technology Transition Between the Laboratory and System Program Office.....	25
US Army Corps of Engineers Technology Adoption Process (CETAP) Study .....	25
Federal Technology Commercialization Field Study .....	26
Summary .....	27

	Page
III. Methodology .....	29
Overview .....	29
Research Design .....	29
Questionnaire Design and Development .....	31
Personnel Background Information .....	32
Technology Push Versus Market Pull .....	32
Transition Process Implementation .....	33
Lessons Learned .....	33
Interview Administration .....	34
Data Analysis .....	35
Limitations .....	36
Summary .....	37
IV. Analysis and Results .....	38
Introduction .....	38
Wright Laboratory Technology Transition Cases .....	39
Maintenance-Free Advanced Aircraft Battery .....	39
Findings: Developing Organization Perspective .....	40
Barriers: Developing Organization Perspective .....	43
Bridges: Developing Organization Perspective .....	44
Findings: Using Organization Perspective .....	45
Barriers: Using Organization Perspective .....	47
Bridges: Using Organization Perspective .....	49
Halon Replacement for Aviation Systems .....	51
Findings: Developing Organization Perspective .....	52
Barriers: Developing Organization Perspective .....	55
Bridges: Developing Organization Perspective .....	56
Findings: Using Organization Perspective .....	56
Barriers: Using Organization Perspective .....	58
Bridges: Using Organization Perspective .....	59
Armstrong Laboratory Technology Transition Cases .....	61
Rapid Optical Screening Tool (ROST) .....	61
Findings: Developing Organization Perspective .....	61
Barriers: Developing Organization Perspective .....	64
Bridges: Developing Organization Perspective .....	65
Bioventing Process .....	66
Findings: Developing Organization Perspective .....	67
Barriers: Developing Organization Perspective .....	70
Bridges: Developing Organization Perspective .....	71

	Page
Findings: Using Organization Perspective.....	72
Barriers: Using Organization Perspective.....	73
Bridges: Using Organization Perspective.....	73
Ion Vapor Deposition (IVD).....	74
Findings: Using Organization Perspective.....	76
Barriers: Using Organization Perspective.....	79
Bridges: Using Organization Perspective.....	80
Key Findings: Barriers and Bridges.....	82
Unique to the Transition of Environmental Technologies.....	82
Important to the Transition of Environmental Technologies.....	83
End-User: SPO Versus Operational Field Organization.....	87
Summary.....	91
V. Conclusions and Recommendations.....	92
Introduction.....	92
Managerial Challenges.....	92
Recommendations for Change.....	93
Recommendations for Future Research.....	94
Technology Transfer.....	95
Individual Case Study.....	95
Development of Environmental Technology Transition Guide.....	95
Measures of Success.....	96
Role of Private Industry.....	96
The External Environment.....	96
Air Force Environmental Technology Policy and Organizational Structure.....	97
Thesis Summary.....	99
Appendix A: Interview Questions.....	101
Bibliography.....	106
Vita.....	109

## List of Figures

Figure	Page
2.1. Weapon System Acquisition Process.....	13

## List of Tables

Table	Page
2.1. Total Estimated Cleanup Costs in BRAC Budget and Cleanup Plans .....	12
2.2. Summary of Barriers to Technology Transition.....	20
2.3. Summary of Bridges to Technology Transition .....	24
4.1. Summary of Barriers and Bridges to Transition of Maintenance-Free Battery .....	50
4.2. Summary of Barriers and Bridges to Transition of Replacement Agent for Halon, HFC-125 .....	60
4.3. Summary of Barriers and Bridges to Transition of the ROST System.....	66
4.4. Summary of Barriers and Bridges to Transition of the Bioventing Process .....	75
4.5. Summary of Barriers and Bridges to Transition of the IVD Aluminum Process .....	80
4.6. Summary of Findings From Environmental Technology Transition Cases.....	81
4.7 Summary of Barriers and Bridges, Unique and Important, to Transition of Environmental Technologies.....	88
4.8 Summary of Differences and Similarities Between Weapon Systems and Operational Field Organizations.....	91

**Abstract**

Environmental policy, social factors, individual behavior, and environmental technologies are key factors in improving the current condition of the environment. The Department of Defense (DoD) is not immune to these aspects, as its actions have and will continue to impact the environment in which they conduct operations.

The objective of this research is to analyze the environmental technology aspect of improving environmental conditions. Of particular interest, what barriers and bridges are encountered when an Air Force laboratory transitions environmental technologies to an end-user: operational field organization or major weapon system. The research employs a case study methodology to analyze five environmental technology transition efforts within the Air Force.

Several key findings identify barriers and bridges specific to the transition of environmental technologies. They include: oversight of environmental protection agencies, the difficulty in clearly defining the end-user, and the need to demonstrate environmental technologies to potential end-users. Further analysis of the case studies indicate that many of the barriers and bridges encountered in the transition of environmental technologies are also encountered in the transition of general technologies. In addition, the researcher provides recommendations for change, and offers future opportunities for research in the area of environmental technology transition.

# AN EXPLORATION OF ENVIRONMENTAL TECHNOLOGY TRANSITION FROM THE LABORATORY TO THE FIELD

## I. Introduction

### Background

Human activities have major impacts on the environment. Since World War II, these impacts have increased dramatically in scale, rate, and form, as the world entered a period of unprecedented economic and population growth (21:31). Environmental problems can be found at the local, regional, national, and global level. Some examples include:

1. More than 50 percent of the wetlands of the contiguous United States were lost by 1990.
2. Between 1980 and 1990, the average annual rate of deforestation worldwide was approximately equivalent to an area the size of the state of Georgia.
3. The United States put almost 5 billion metric tons of carbon dioxide in the atmosphere in 1991, almost entirely from the use of fossil fuels.
4. In 1988, 1.25 billion people worldwide breathed air containing unhealthy concentrations of suspended particulate matter.
5. In the past 45 years, almost 11 percent of the earth's vegetated surface has suffered significant soil degradation caused mainly by deforestation, agricultural activities, and overgrazing. (21:32)

Environmental policy, social factors, individual behavior, and environmental technologies are key factors in determining whether these and other environmental conditions worsen or improve (21:32). With current technologies, it will be difficult to attain a sustainable level of environmental health given the expected levels of population



and individual growth. Trends indicate population growth is slowing and economic activity is increasing rapidly. Based on these two trends, the only realistic option during the next several decades for decreasing the environmental impacts of a population as a whole is to reduce the environmental impact of individuals. One way of accomplishing such a change is to encourage environmental technology and social practices that affect technology that can improve the environment (21:33).

### **Department of Defense Implications**

The actions of the Department of Defense (DoD) has and will continue to impact the environment in which they conduct operations. The current budgetary and regulatory environment, coupled with the recent closures of military installations, have forced the DoD to evaluate the manner in which it proceeds with environmental issues.

The ability to effectively and efficiently transition environmental technology is becoming an increasingly important consideration for both the Air Force and the federal government in general. The regulatory environment, combined with budgetary constraints, have forced the DoD to take a proactive approach to finding solutions to these environmental problems. One such solution is the development and implementation of new environmental technologies. As evidenced by the published goals of the Air Force Material Command (AFMC), operating quality installations is one of the top-five priorities within the Command. To complement this goal, sustaining technological superiority also tops the Command priority list. In order to achieve these goals, AFMC has established a

plan to aggressively execute environmental pollution prevention, compliance, and restoration programs (19:2).

The downsizing of the military has brought with it the approved closures of 70 major domestic military installations, as recommended by the Base Realignment and Closure (BRAC) Commissions of 1988, 1991, and 1993. Of those, 24 are the responsibility of the Air Force. As of 1 January 1995, only 36 of the original 70 had been officially closed (27). Due to the need to properly restore these sites prior to transfer to local governments or other agencies, approximately 7,300 military installation sites are programmed for some form of hazardous waste remediation under the Defense Environmental Restoration Program (DERP) (3:27). Without innovative technologies, this task will prove to be an unacceptable burden to the nation's taxpayers.

Not all concerns associated with environmental issues are the result of the recent drawdown. On 6 October 1992, then President George Bush signed the Federal Facility Compliance Act (FFCA) of 1992, Public Law 102-386. The FFCA allows states and the Environmental Protection Agency (EPA) to assess civil fines and penalties against federal agencies, including the DoD, for failing to comply with state solid and hazardous wastes laws (8:Section 1, 1). This act enables the EPA to conduct on-site inspections under their new Multi-Media Enforcement/Compliance Initiative. DoD concerns regarding the FFCA are genuine based on the fact that a majority of DoD contaminants are classified as hazardous waste, and are stored in numerous installation landfills (3:27-28).

As a research unit of AFMC, Armstrong Laboratory (AL) is chartered with the task of providing new environmental technologies to assist the Command, and the Air Force, in

addressing these environmental issues. The environmental technologies developed by AL are tailored to meet the requirements of operational field units, including major military installations. Because of this, the technologies developed are not under the sponsorship of a single manager; instead, they have multiple users across multiple commands. AL has responded to this situation by requesting the Air Force Institute of Technology (AFIT) conduct an in-depth analysis of the process used to transition AL environmental technologies, identify impediments to the transition process, and identify bridges that will improve the current environmental technology transition program at AL.

### **Definition of Terms**

Within the DoD, it is not uncommon to find a language that is specific to a unit or command. The environmental community is no exception. The following list of terms will be used throughout this research to describe issues involved with the transition of environmental technologies.

1. Environmental technology is a technology that advances sustainable development by reducing risk, enhancing cost effectiveness, improving process efficiency, and creating products and processes that are environmentally beneficial (22:9).

#### **Environmental Technology Categories:**

- 1a. Avoidance technologies avoid the production of environmentally hazardous substances. Synonymous with pollution avoidance (22:9).
- 1b. Monitoring and Assessment technologies establish and monitor the condition of the environment (22:9).
- 1c. Control technologies render hazardous substances harmless before they enter the environment (22:9).
- 1d. Remediation technologies render harmful or hazardous substances harmless after they enter the environment (22:9).

- 1e. Restoration technologies include methods designed to improve ecosystems that have declined due to environmental neglect (22:9).
2. Technology is defined as intellectual knowledge, processes, or products developed by the Air Force.
3. Technology insertion is defined as the progression of product and process technology to initial production or use for Air Force application to a new or fielded system; the movement of technology into operational use (1:B-6). Used synonymously with technology transition for purpose of this research.
4. Technology transfer is defined as the movement, or sharing of technology outside the Air Force to other governmental agencies or to industry for commercialization; horizontal movement (1:B-6).
5. Technology transition is defined as the progression of product and process technology from laboratory development to further development for an Air Force application to a new or fielded system (vertical movement). This includes infusion of non-Air Force developed technology for Air Force use (1:B-6; 15; 2:1).

### **Research Objectives**

The objective of this research is to identify factors important to improving the environmental technology transition process between AL and their operational customers. The research will provide case studies of environmental technology transition efforts from both AL and Wright Laboratory (WL). Case studies involving WL are included as a tool for comparing the processes and methodologies with those of AL. Research objectives will be used to direct this research and provide sound recommendations. The research objectives are as follows:

1. Identify, through analysis of current literature, the potential barriers to, and bridges that aid in the execution of, a successful technology transition.
2. Identify specific potential barriers impeding the successful transition of environmental technologies in the Air Force; i.e. which barriers are unique to

environmental technologies and which barriers are common to those found in the literature.

3. Analyze the differences between transitioning environmental technologies from laboratory to major weapon system programs, through System Program Offices (SPOs), and from laboratory to operational field organizations and determine the relative success of these types of transitions.

### **Scope of Research**

It should be understood that these case studies deal with the transition of environmental technologies from WL to major weapon systems, and from AL to Air Force units with an operational mission. Each case takes an in-depth approach to analyzing the methods used to transition environmental technologies from each laboratory respectively. While an AFMC policy exists on the transition of technology, each AFMC Product Center, Laboratory, or Depot has its own internal methods and policies for transitioning technology. Therefore, the results and recommendations of these case studies only provide insight to the environmental technology transition procedures at WL and AL. Generalizations can, however, be applied to the environmental technology transition process from AL to other field organizations and from WL to other weapon systems. The goal of this research effort, specifically the case studies, is to lay an environmental technology transition foundation which future research efforts can expand upon.

### **Thesis Overview**

Chapter Two focuses on barriers and bridges to technology transition found in the documented literature. Discussion focuses on the transition as well as the adoption of new

technologies. An analysis of case studies provides insight into the impacts of these transition barriers and bridges. Chapter Three introduces the methodology used in this research. Discussion focuses on case studies and their use in exploratory research. The chapter concludes with the development and explanation of the interview questionnaire. Chapter Four provides an analysis of the data collected from AL, WL, the Air Force Center for Environmental Excellence (AFCEE), and the Human Systems Center (HSC). The examination will focus on data collected from interviews and reviewed documents. The results of this analysis provide the basis for conclusions, found in Chapter Four, and recommendations for change and future research, found in Chapter Five. A foundation from which future research should proceed is also discussed in Chapter Five.

## **II. Literature Review**

### **Overview**

The purpose of this chapter is to examine previous literature related generally to the transition and/or adoption of technology, and specifically to the transition of environmental technologies. The first section of this chapter describes the emphasis of environmental issues at military installations, including those slated for closure. The second section of the chapter briefly introduces the reader to the weapon system acquisition and requirements generation processes. Next, discussion focuses on previously identified technology transition barriers and bridges. Finally, the chapter concludes with an analysis of previous case studies which examine the transition of both technology in general and environmental technology, specifically. These last two sections provide a more focused understanding of previously examined barriers and bridges to the transition process and the impact they have in real world settings.

### **Environmental Legislation**

With a clear understanding of the importance of environmental issues in today's society, DoD actions must reflect on the influence this factor has on daily operations. Environmental regulations are a powerful manifestation of this influence. The DoD is responsible for complying with all environmental regulations established at the local, regional, and national levels. Information on the following environmental legislation is provided to ensure the reader has a basic understanding of the expectations placed upon

the DoD, and the penalties associated for failing to meet those expectations. The focus of this discussion is on federal regulations and not the policies of individual states, since many states operate mini-Environmental Protection Agency (EPA) organizations which have established regulations of their own.

The Resource Conservation and Recovery Act (RCRA) was established to regulate the release of hazardous waste and toxic substances. RCRA applies to any individual, firm, company, corporation or agency of the federal government that generates, transports, stores, treats or disposes of these substances (7:31). The program is managed by an extensive permitting process administered at the federal and state level. The EPA has the authority to issue civil penalties of up to \$25,000 for each day of violation.

The Clean Air Act (CAA) is based on eight major sections designed to control air pollution and reduce emissions of hazardous air pollutants. The standards defined in the CAA define the level of air quality necessary to protect the public health (7:32). The individual states are then responsible for the direct regulation of the sources of air pollution. As with RCRA, a penalty of up to \$25,000 for each day of violation may be issued for noncompliance. In 1990, the CAA was amended with stricter air quality standards, to include 189 new substances designated as hazardous air pollutants, and required the EPA to regulate and limit the emissions of these substances to the level of the "maximum available control technology" (7:32).

The Clean Water Act (CWA) regulates the discharge of pollutants into navigable waters. This is accomplished by the issuance of permits under the National Pollutant Discharge Elimination System (NPDES). The CWA stipulates that NPDES permits must:



1. Limit the discharge of effluents based upon national technology based guidelines, and where necessary, water quality standards under certain sections of the Act.
2. Impose schedules of compliance for the permittee to complete construction or to install new pollution control technology.
3. Require permittees to monitor their discharges and report results and any violations to the permitting agency. (7:33)

Penalties under the CWA are more severe than those of the previous two Acts. Fines can range up to \$125,000 per day.

The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), or Superfund Act, differs from the previous three Acts in that it is concerned with the remediation of environmental contamination. CERCLA relies on other laws that deal with hazardous waste. The EPA lists all cleanup sites on the National Priorities List (NPL) as well as a list of the most hazardous waste sites in the United States (7:34).

### **GAO Findings**

For decades, DoD organizations have generated, stored, recycled, and disposed of hazardous waste. Types of hazardous waste found at most DoD installations include solvents and corrosives; including paints, strippers, and thinners; metals; and unexploded ordnance (31:10). Contamination usually occurs into nearby soil or groundwater through disposal, leaks, or spills.

Of significant importance to the science and technology (S&T) community, the GAO report concludes that technology used to clean hazardous waste sites is either not available

for certain contaminants or is inefficient and not cost effective. Concern has been expressed that major hazardous waste sites will remain contaminated, at both operating installations and those slated for closure, unless new technologies are developed to address these issues. The cleanup of groundwater and unexploded ordnance were cited in the report as specific problem areas.

With groundwater, the current technology used is the "pump and treat" method where contaminated water is pumped to the surface where it is then treated. The problem is this technology can cost millions of dollars, take decades, and still leave groundwater contaminated (31:27).

The hazards associated with unexploded ordnance are two-fold. First, from an environmental standpoint, ordnance contains petroleum products, metals, and other hazardous compounds. With unexploded ordnance, safety issues are also of great concern. Current technology is limited in its detection capabilities to ordnance buried less than three feet.

The GAO findings reflect serious problems with the cleanup and transfer of closed military installations. In its 1995 budget request, the DoD estimated cleanup costs for the 123 installations on the list at that time at \$4.0 billion. However, in estimates developed by 84 of the installations for their April 1994 cleanup plans, the total bill had increased to \$5.4 billion (31:3). A summary of this information is provided in Table 2.1.

TABLE 2.1

**TOTAL ESTIMATED CLEANUP COSTS IN BRAC BUDGET AND  
CLEANUP PLANS ( Dollars in millions) (31:17)**

	Number of Cleanup Plans	FY 1995 BRAC Budget Estimates	Cleanup Plan Estimates	Difference
Air Force	26	\$1,674	\$1,207	(\$467)
Army	19	693	1,268	575
Navy	34	1,356	2,882	1,526
<b>Total</b>	<b>79</b>	<b>\$3,723</b>	<b>\$5,357</b>	<b>\$1,634</b>

### **Weapon System Acquisition**

In order to clearly understand how technology is transitioned to a weapon system program, it is imperative that the reader first understand the defense acquisition process.

The Defense Systems Management College defines a defense acquisition system as:

A single uniform system whereby all equipment, facilities, and services are planned, developed, acquired, maintained and disposed of by the DoD. The system includes policies and practices that govern acquisition, identifying and prioritizing resource requirements, directing and controlling the process, contracting, and reporting to Congress. (13:1)

Prior to the establishment of a System Program Office (SPO) to manage the undertaking described previously, a requirements generation process takes place. This analysis is based on a continuing process of assessing the DoD's current capabilities to meet today's threat, while taking into consideration any opportunities for technological advancement. If a deficiency exists in the current capabilities or a technological development is available, an analysis process is started in order to find the best solution to remedy the situation. Only after all non-material solutions are evaluated, does the DoD

look for material solutions. Once the determination to pursue a material solution is made, a Mission Need Statement (MNS) is generated by the major operating commands (Air Combat Command (ACC) and Air Mobility Command (AMC)) that documents the situation in non-system specific terms.

The generation of a MNS is not the end of the requirements generation process. Once the operating command has submitted a MNS, a validation and approval process is conducted to ensure the deficiency or technological opportunity warrants full program status. Once the MNS has been reviewed and approved by the Joint Requirements Oversight Council (JROC) and the Defense Acquisition Board (DAB), the program enters Phase 0, Concept Exploration and Definition, where concept direction studies are initiated. Figure 2.1 provides a graphical representation of this process.

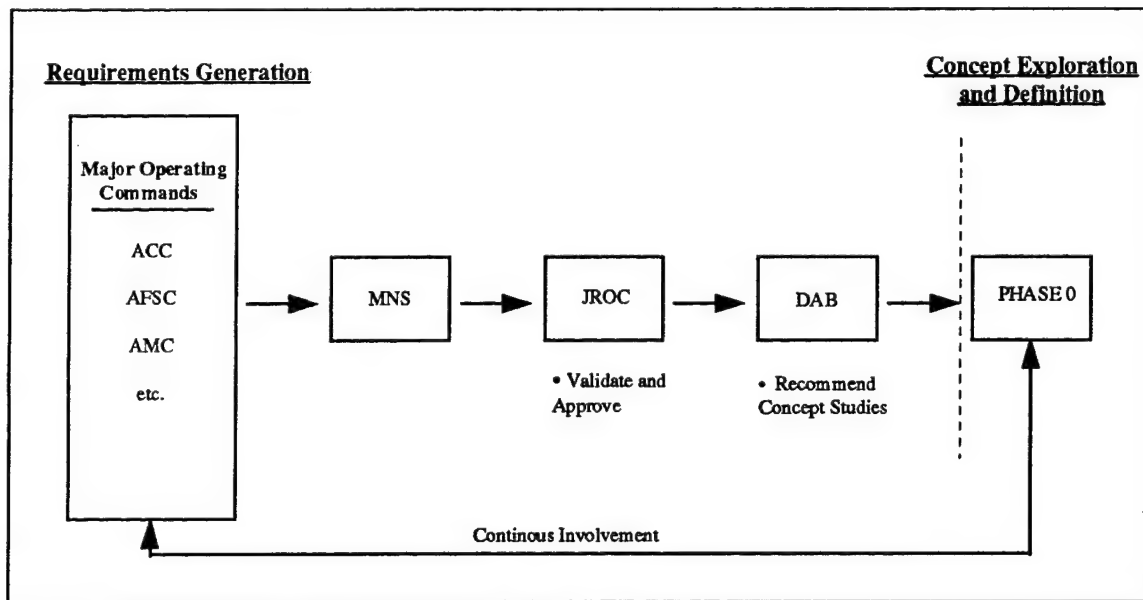


Figure 2.1 Weapon System Acquisition Process

The relationship between the SPO and the laboratory is crucial to the success of the development and eventual production of a new weapon system. The SPO is responsible for ensuring that a system is developed and produced. In many cases, this management takes place via the oversight of government contractors who are charged with integrating the complete weapon system into a producible end-item.

Since most major weapon systems involve at least some level of new technology, the laboratory is vital to the development phase of the acquisition lifecycle. Often the laboratory is responsible for developing new technologies that enhance the performance of new weapon systems. The successful transition of these technologies is the linchpin in this SPO-laboratory relationship.

### **Technology Transition**

By combining the potential penalties associated with failure to comply with environmental regulations, and the fact that the DoD budget continues to shrink, it is clear that the Air Force can ill afford to fail in its environmental compliance efforts. While current technologies are an integral part of meeting this challenge, the GAO report highlights the importance of developing and fielding new environmental technologies if the Air Force is to meet its expectation of full compliance.

The remainder of this chapter focuses on previous research that highlights the potential barriers and bridges that are encountered in the transition of technology. Some of the following research deals with the transfer of technology instead of the transition role. It is important to remember from Chapter One definitions that the key differentiation between

technology transfer and transition is to whom the technology has been passed. Transfer defines technology movement that is external to the developing organization, while transition deals with the movement of technology between functions within the same organization. Therefore, expected barriers and bridges found in technology transfer are likely to be similar to those encountered in a technology transition effort.

### **Barriers**

The transition of technology is a process involving human interaction, new technology, and bureaucratic red tape; all of which have the potential for raising barriers to a successful transition. Substantial research has focused on identifying what barriers exist and how they affect an efficient technology transition program.

Guilfoos classifies all barriers into three main categories: technical, regulatory, and people (17:27). Other researchers identify similar barriers (5:17; 4:42-43; 29:66). While barriers are sometimes necessary to ensure safety, prevent past mistakes from reoccurring, and provide some form of standardization, a majority of barriers only limit the transition process.

**Technical Barriers.** Technical barriers are those that simply involve technical issues. Once the technology is developed, will it actually work in an operational environment? Guilfoos includes technical risk, lack of operational test data, and a defined requirement as key technical barriers (17:28). Technical barriers are present whenever the technology involved is new and has not been used before. It does not necessarily mean that the technology is "complex technology"; it can be elementary in concept. Technical barriers

usually involve fear of the unknown that comes from using a new technology. The GAO further notes that fear of technical risk at the field level is a barrier in the development of environmental cleanup technologies (31:34). Questions about how the technology will impact the organization or the program, or whether it will work, are typical for the technical barriers (17:28). Ensuring the user receives what it needs and that the technology resolves its deficiency is another technical barrier. It is not cost or time effective to develop technology for technology's sake (17:28).

Gummere's research revealed that technical risk and the willingness to accept it was important to successful technology transition (18:101). It was perceived by personnel at what was then Wright Research and Development Center (WRDC), that risk aversion exhibited by the SPO is a barrier to technology transition (18:101).

Research conducted on the Microelectronics and Computer Technology Corporation (MCC) by Smilor and Gibson found that technology that is easy to understand, demonstrable and unambiguous is easier to transfer than technology that is harder to understand, more difficult to demonstrate and more ambiguous (25:9). Smilor and Gibson refer to this phenomena as equivocality; where the easy to understand technology is categorized as low in equivocality.

**Regulatory Barriers.** Regulatory barriers are those involving the most *red tape*. As part of the regulatory arena, specification barriers exist when there is a need to have the technology meet existing specifications, or when current specifications are not applicable to the new technology. Technical orders and regulation barriers usually involve the user and their unwillingness to implement new technology without new technical orders or

regulations addressing the technology. Long procurement lead times are a concern of both the user and the technology developer (17:28). In its report, the GAO also acknowledged the time needed to develop new technologies as a concern (31:34). Diminishing dollars and vanishing vendors are complements of each other, and are prevalent in today's defense environment. The AFMC environmental community is aware of the diminishing budget barrier, as evidenced by a reduction of funding for the DERP program for the 1996 and 1997 fiscal years (19:3).

**People Barriers.** Much research has focused on what Guilfoos classifies as people barriers. Unfortunately, these barriers remain some of the most difficult to overcome (17:28; 6:33). Barriers usually arise when people involved with the development and transition efforts are not aware of the capabilities of the new technology. The problem is compounded when the people who are technically unaware have no desire to become technically educated. Negative opinions are based on perceptions from earlier experiences with a similar technology, or from listening to other people comment on their experiences (17:28). A review of the literature also indicates many people involved with technology considered themselves too busy to look at anything new; technology transfer was not an important job function (17:30; 29:66).

Smilor and Gibson's research provide additional people barriers. Based on survey, interview, and archival data, Smilor and Gibson found that lack of communication between the two parties involved was a key barrier to overcome. Successful communication includes establishing both passive and active links (25:7). Passive links



include research reports, journal articles, computer programs, and video tapes; while active links are direct, person-to-person interactions.

Two additional key barriers emerged from Smilor and Gibson's research: distance and motivation. Distance deals not only with geographical separation, but also with the cultural differences between the parties involved. Research indicates that transitions are more likely to be successful if both the geographical distance and the cultural difference are minimized (25:9). Finally, the MCC study found that the higher the motivation, for both the developers and the users, the greater the potential for a successful transition. Motivation should vary by importance of the technology involved, and how transition is viewed within an organization (25:9).

Majchrzak, in research focusing on the development and adoption of advanced manufacturing technology (AMT), identifies similar reasons why people resist new technology:

1. Demands of retraining.
2. Actual or feared loss of status.
3. Fear of job loss.
4. Breakup of work groups.
5. Loss of intrinsic job satisfaction.
6. Erosion of pay differentials.
7. Fear about actual losses in earnings.
8. Unfavorable experience with similar changes.

9. Unfavorable attitudes of peers toward the new technology.

10. Fears about management's ability to handle the change. (20:248-249)

Carr describes similar people barriers in his research of technology transfer from federal laboratories. He concludes that information gaps between the laboratories and industry (user) limit technology transfer (5:17). Industry is at fault for not understanding what technologies exist in the laboratories, and the laboratories are at fault for not having a clear idea of what industry needs (5:17).

Edwards' research supports the findings of Carr in identifying the importance of the developer-user relationship. His research found that technology cannot efficiently be pushed upon a user. Instead, the movement of technology is effected by the vision of managers and engineers pulling technology. This vision is a combination of imagination and demonstration that effects the transition process in such a manner that technologies pulled by the user have an increased likelihood that the technology will be transitioned successfully (14:46). In order to pull a technology from the developing organization, it is imperative that the end-user is able to integrate its requirements with the capabilities of the technology. A summary of barriers found in technology transition efforts is provided in Table 2.2.

TABLE 2.2

## SUMMARY OF BARRIERS TO TECHNOLOGY TRANSITION

<b><u>Technical Barriers</u></b>	
Technical Risk	Lack of operational test data
Lack of a defined requirement	Risk aversion
Equivocality	
<b><u>Regulatory Barriers</u></b>	
Lack of technical orders for the user	Long procurement lead times
Lack of regulations defining the use of the technology	Diminishing federal research and development budget
<b><u>People Barriers</u></b>	
Unaware of new technology	Unwarranted negative opinions
Demands of retraining	Actual or feared loss of status
Fear of job loss	Breakup of work groups
Loss of intrinsic job satisfaction	Erosion of pay differentials
Unfavorable attitudes of peers towards new technology	Fears about management's ability to handle the change
Fear about actual losses in earnings	Unfavorable experience with similar changes
Lack of communication	Lack of motivation
Too busy	Distance (geographical and cultural)
Technology push versus market pull	

## **Bridges**

Research into the successful traits of technology transfer and transition focus primarily on the actions and attitudes necessary to overcome many of the barriers previously discussed. Through the study of three federal laboratories, two private laboratories, and one research institute, Souder, Nashar, and Padmanabham identify seven practices that are factors of successful technology transfer:

1. Use of analytical practices in the measurement of transition effectiveness.
2. Providing testing facilities and related support for potential technology users.
3. Pro-actions, including newsletters, meetings, training courses, one-on-one consulting, and advertising.
4. Ability of the developing agency to seek out key players (champions, high-level executives for protection) at the user organization and build a team around them.
5. The recommendation of competent and respected third-party organizations.
6. The technology transferred had tangible value, was able to be adopted piecemeal, and could be adapted specifically to the user's needs.
7. Establishing developer-user partnerships and involving the user early in the process. (28:9-11; 6:33)

Research into the inward technology transfer practices of ICI Chemicals and Polymers Ltd. (ICI) found similar results. Four common themes were found within the ICI inward technology transfer process:

1. Strong external operating environment; focus on growing industries.
2. Development of good working relationships both within the developing organization and the using organization, and between the two.
3. Strong leadership.
4. A "spirit" and a sense of excitement; a willingness to explore and learn. (30:36-37; 6:33)

Guilfoos agrees that being able to fit the technology to the system, involving the user through out the entire transition process, and developing strong working relationships are key traits of a successful transition program (17:31).

Creighton, Jolly, and Buckles establish two distinct categories to capture bridges that their research has identified: formal and informal elements. Formal elements are those that are identifiable and manageable. They include:

1. Establishment of an organization to lead the transition effort.
2. Project established to identify technology effort.
3. Clear and thorough documentation of transition process.
4. Distribution of information. (11:69-71)

Informal elements are those that are not clearly identifiable and difficult to manage.

They include:

1. Linking between the developer and the user.
2. Capacity to transmit and receive information; both developer and user.
3. Credibility of parties involved.
4. Willingness of parties involved to communicate ideas.
5. Reward mechanism. (11:72-77)

A case study focusing specifically on technology transferred from Sandia National Laboratories to the private sector provides additional support for the bridges discussed previously and offers some additional points for the successful transition of technology. While the study analyzed a transfer from government to private sector, the lessons learned provide useful information. First, the technology must fit the strategic plan of the user.

Timing is critical, as interest and technology availability must coincide (34:26). Landmark inventions (major basic inventions) offer good potential for product development (34:26). Also, if a technology can be applied across diverse markets, its attractiveness to the user is increased. A broader market base allows the developer to use a core technology to develop many technologies (34:27). It is also important the developing organization have sufficient resources to successfully develop and market technologies. Finally, it is essential the developing organization have a champion to push the development of the technology. The champion should have sufficient decision making capabilities in order to provide a positive impact (34:27; 6:33). A summary of bridges found in successful technology transition efforts is provided in Table 2.3.

TABLE 2.3

## SUMMARY OF BRIDGES TO TECHNOLOGY TRANSITION

Newsletters, meetings, training courses, consulting, and advertising	Providing testing facilities and support to technology users
Measurement of transition effectiveness	Ability to seek out key players (champions)
Recommendations of third-party organizations	Developing developer-user partnerships and involving the user early
Technology has tangible value to the user	Strong leadership
Sufficient resources available for development	A "spirit" and willingness to explore and learn
Strong external operating environment	Diverse markets for the technology
<b><u>Formal</u></b>	
Clear, thorough documentation of information	Project established to identify technology effort
Organization to lead effort	Distribution of information
<b><u>Informal</u></b>	
Linking between developer and user	Reward mechanisms
Credibility of parties involved	Willingness of parties to communicate ideas
Capacity to transmit and receive information	

**Case Studies**

Case studies focusing on technology transition are a valuable tool for analyzing the effects the previously discussed barriers and bridges have on a specific organization(s). Three such case studies on technology transition are directly applicable to this research

and were chosen for their representativeness of organizations conducting technology transition efforts. They are summarized in the following sections.

**Technology Transition Between the Laboratory and System Program Office.** In Gummere's 1989 thesis effort, attention was focused on studying the technology transition process between WRDC and the Advanced Tactical Fighter (ATF) SPO. This case study analyzed the barriers of effective technology transition between the two organizations. Individuals at WRDC, the ATF SPO, the Aeronautical Systems Division Engineering Directorate (ASD/EN), and civilian contractors were surveyed for the case study.

The survey results indicate that several of the barriers previously identified were problems in the ATF program. Two key findings identified the perceived importance of the receiving organization in the transition process, and the existence of a resistance barrier to the new technology at the user level (18:90-91). The general communications patterns between the laboratory and the SPO, and the laboratory and ASD/EN were also identified as barriers to technology transition by the survey respondents (18:97).

While not specifically identified as a barrier, the formal mechanisms were rated as not effective, while the informal mechanisms were rated as effective in transitioning technology (18:96). Comments from respondents include:

1. Technology transition is done best on an engineer to engineer basis.
2. Technology transition is a delicate process which requires personal involvement/interaction before an understanding can be achieved between research and product communities. (18:96-97)

**US Army Corps of Engineers Technology Adoption Process (CETAP) Study.**

Research was conducted by the US Army Corps of Engineers (USACE) to address a



perceived lack of standardization in the identification, assessment, and adoption of new technologies. Two issues were identified that confront the Corps regarding the use of new technologies: (1) the ability to adopt new technologies within the existing USACE environment of regulations, engineering guidance, and standard practice; and (2) the ability to assess the effectiveness of USACE technology adoption procedures (32:5).

The USACE technology adoption process is designed to follow a predetermined process. The five steps included in this process are: (1) determine the Army's need; (2) technology gap research and development (R&D); (3) field demonstration; (4) authorization; and (5) application (32:13).

The study results reveal the key barriers to technology adoption within the USACE were: risk associated with unknown performance; time constraints; level of effort necessary; guide specifications; and resistance to change (32:28). In contrast to Gummere's research, the USACE study concludes:

The existing ad hoc technology adoption process does not foster efficient technology management because it does not provide sufficient information on innovative building technologies in a timely fashion. (32:33)

**Federal Technology Commercialization Field Study.** The Huntsville, Alabama, chapter of the Technology Transfer Society was the focus of a field study conducted by Spann, Adams, and Souder. The purpose of the study was similar to the previous two studies in that the focus was on identifying barriers to the technology transfer process. This study takes that focus one step further by analyzing the different perceived barriers from the perspective of the developer and the user.

Underlying technology transfer barriers revealed from this study include:

1. User's resistance, including user's overall resistance to change. Derived from lack of interest, risk aversion, and refusal to admit technical problems.
2. Unknowledgeable users, in both the available technologies and the procedures for transferring the technologies.
3. Government shortcomings including a lack of transfer expertise within the government.
4. Distrust from both the users and the developers. Users were concerned about proprietary ownership, while the developers were distrustful of rivalries between agencies and concerned about conflicts of interest. (29:67)

### Summary

The purpose of this chapter was to present information on literature related to the technology transition process and some of the potential barriers and bridges encountered in this process. The literature review process revealed there was a vast amount of research available on the transition of technology; both from labs to outside users and from labs to users within an organization. Unfortunately, the literature review process also revealed the lack of specific research conducted into the transition or transfer of environmental technologies.

One research effort being conducted by the University of Oklahoma plans to explore the strategic, organizational, and innovation implications of different environmental regulatory regimes on corporations through the use of case study analysis and survey research. Du Pont and Conoco will be studied to explore the relative influence of environmental regulation on innovation.

Case studies are the methodology of choice for the Oklahoma research effort because of the lack of previous research and the perceived ability of case studies to “more richly describe phenomena than one can using quantitative analysis” (23:3). Data will be collected through in-depth interviews at Du Pont and Conoco, with their customers, with regulators, and through interviews with their suppliers.

Unfortunately, a similar situation exists in this research effort with the lack of previous research found covering the transition of environmental technologies. Chapter Three will further address how case studies are used to analyze an organization or event thoroughly and provide exploratory level results that can be used to develop a framework for future research efforts.

### **III. Methodology**

#### **Overview**

The focus of this chapter is on how best to capture the different perceptions from both the developers and the users of environmental technologies. A research method is developed to provide for the orderly and accurate collection and analysis of data. An overall approach to the research is presented, followed by an in-depth discussion of the development of the questionnaire and the administration of the interview to be used in this research effort. The chapter concludes with a detailed discussion of how gathered data will be analyzed to accurately answer the research objectives presented in Chapter One.

#### **Research Design**

Although there has been much written in general about the barriers and bridges encountered during the transition or transfer of technology, minimal research exists that specifically addresses environmental technologies, as evidenced by the literature review in Chapter Two. This research uses case studies to support an exploratory research approach.

Dane defines exploratory research as "an attempt to determine whether or not a phenomenon exists" (12:5). Exploration is applicable when there is not a clear understanding of what might be uncovered during the study (9:117). The exploratory case study allows for the focusing of concepts. In this case, the area of research has not been researched thoroughly and therefore an exploration can be useful to learn about the

problem itself. Case studies allow for the development of hypotheses to be used for analysis in later studies (12:114). Yin adds, "the case study allows an investigation to retain the holistic and meaningful characteristics of real-life events" (35:14).

Case studies usually are limited in their generalizability to a larger population. They do however provide an understanding of organizational functioning, and are useful in determining patterns (26:28). Additionally, case studies are useful in providing managers and students a technique of looking at the entire context of the phenomena in question (23:3).

The initial step in the exploratory study was the literature review. This provided relevant information on the barriers and bridges encountered when transitioning and transferring technology. The literature review revealed limited information as to the likelihood and types of barriers and bridges that would be encountered when transitioning environmental technologies.

As a starting point for the specific case study, information is gathered describing the organizational policies and environmental technology transition processes of both Wright Laboratory (WL) and Armstrong Laboratory (AL). To further define the transition process of each organization, a representative sample of five case studies (two from WL and three from AL) are studied in detail. Data are collected describing the technology transitioned, the transition process encountered with the specific technology, and most importantly, data are collected examining the barriers and bridges that contributed to an unsuccessful or a successful transition. Analysis then focuses on comparing the results

from the two laboratories, and comparing the results to the barriers and bridges identified in the literature review.

### **Questionnaire Design and Development**

Once the preliminary data describing the technology transitioned, the transition process, and the key barriers and bridges has been gathered, formal interviews with key transition personnel are conducted. A major strength of the case study is the opportunity to use many different sources of evidence. This opportunity to use multiple sources far exceeds that in other research strategies (35:90). The use of multiple sources of evidence allows the researcher to address a wider spectrum of historical, attitudinal, and observational issues. Yin identifies the most important advantage to using multiple sources of evidence is the development of converging lines of inquiry, basically supporting conclusions in a case study as more accurate if they are based on several different sources (35:91).

The target sample for interviews includes key personnel involved in the transition from both the developing laboratory (AL or WL) and the using organization. Questions are focused in such a manner as to provide specific details that support the research objectives. Topics were developed based on two sources; information gathered in the literature review; and successfully implemented questionnaires from previous research. The list of interview questions is provided in Appendix A. The questionnaire addresses topics to include the following.

**Personnel Background Information.** This section focuses on both the characteristics of the personnel involved and the technology being transitioned. The overall goal of this initial group of questions is to identify whether some of the people barriers found in the literature review are found in these cases. Questions one and two are demographic in nature and are included as a prelude to question three, and to provide additional support for the experience level of the personnel involved with the transition. Questions three and four focus on how familiar the respondent is with both the processes his organization uses to transition or receive new technologies, and how familiar he is with the technology being transitioned. Research discussed in Chapter Two indicates an underlying transition barrier is the lack of knowledge found with both the developer and the adopter with regards to the transition process and the technologies available (29; 66-67). Questions five and six are used to determine the role and the responsibilities of the respondent within his organization and how he classifies his position; technical or managerial. Guilfoos indicates that when a person is responsible for other tasks besides the transition project, the likelihood of success is decreased (17:30). Also, Gummere's research found transition efforts were most successful when completed between engineers (18:96-97).

**Technology Push Versus Market Pull.** The focus of this section of questions is on requirements generation. The first question is included to determine whether the technology already exists in the laboratory (technology push), and if so how well it was marketed to potential users; or if a need was identified by a potential user and the technology developed to meet that need (market pull). Chapter Two discusses the results of Edwards' research that found most successful transitions are driven by market pull

(14:46). With Smilor and Gibson's research designating distance as a barrier to successful transition efforts, question three focuses specifically on determining what effect multiple, distant users have on success in these cases versus the transition to a single, centrally located organization.

Chapter Two also discusses the requirements generation process used in major weapon system procurement. Question four is included to try and determine whether or not such a stringent process is in use with the transition project in question. It is the preliminary belief of the researcher that there exists a much less defined requirements generation process in the operations-level environmental community than there exists within the weapon system procurement community.

**Transition Process Implementation.** The questions from this section of the questionnaire are intended to determine what formal and informal elements were present during the transition of the technology in question. Information gathered on the existence, or lack thereof, of formal and informal elements found in the cases will provide additional support in determining barriers and bridges to a successful transition. Questions one and two specifically focus on the formal elements as discussed in the research of Creighton, Jolly and Buckles. Question three is derived from the same research, with a focus on identifying the informal elements involved in the transition effort.

**Lessons Learned.** This final section provides a specific line of questioning with the intent of identifying potential barriers and bridges encountered in the transition effort. The questions are developed based upon information discussed in the literature review. A separate list of questions were designed for both barriers and bridges. At the end of the



each list, a generic question is posed to the respondent asking them to identify any additional barriers or bridges they encountered in this transition effort. The respondent will be encouraged to elaborate on these barriers and bridges in order to make a correct identification of elements not encountered in other transition efforts.

As a final preparation before the questionnaire was administered to the respondents, a pilot study was conducted. The pilot study was used to help the researcher refine the data collection process with respect to both the content of the data and the procedures used in the collection of the data (35:74). Applicable changes in the questionnaire were made prior to the first interview.

### **Interview Administration**

The interview process focuses on the predetermined questionnaire previously discussed. Using a questionnaire is not meant to limit or structure the interview. The goal is to conduct the interview in a nondirective manner. A nondirective approach allows for flexibility in discussion, allowing the respondent to volunteer relevant facts and opinions (10:35). New perspectives and new lines of information are opened with nondirective interviews. The questionnaire provides the interviewer and the respondent with a script that ensures all relevant information is gathered from the interview. It also provides the respondent some assurance that the interview is not just a *fishing expedition* (10:35).

To aid the interview participants, the questionnaire was provided to the respondents in advance of the formal interview process. The researcher discussed all research objectives with the participants prior to the interview. The researcher briefed the interview

participant on non-attribution of the information provided, and assured the respondent that the data is to be used only for case study development and not to determine fault.

A successful interview is characterized by the researcher's ability to gather available data from the respondent, ensure the respondent has a clear understanding of his role in the interview process, and adequate motivation by the respondent to cooperate (9:271). The researcher defined the objectives and data sought from the interview in addition to the role the of the respondent. Finally, the researcher motivated the respondent by addressing the fact that the final product is only as good as the information gathered for analysis.

All pertinent information was recorded by the interviewer. In order to ensure the accuracy of the information, a tape recorder was used at each interview with the permission of the respondent. Tape recording has the advantage of providing a more complete record, one that can be reviewed later (10:39). Notes were taken as a back-up to the tape system, with an emphasis on collecting only important points, not transcribing the complete interview.

### **Data Analysis**

The focus of the analysis is the comparison of the results in several environments. The environments include comparing the barriers and bridges identified in the cases to the barriers and bridges discussed in the literature review, and comparing the barriers and bridges identified in the cases to see what effect an operational versus weapon system focused end-user has on the success of the transition. In this research effort, operational

organizations are defined as base level end-users, where weapon system focused end-users are concerned with aircraft, missiles, and other systems of this type.

The first step in this comparison process is to analyze the document search findings and interview responses for common, recurring themes. These provide an insight into the important topics encountered during the transition. Discussion of the data provides a detailed exploration of the transition effort itself, differences, similarities, barrier, and bridges encountered among the specific transition cases.

In direct support of the second research objective, comparing the barriers and bridges experienced within each of the cases allows for an analysis and ultimately, a determination of the differences and similarities of the barriers and bridges document in the case studies with the documented barriers and bridges found in the literature review. Comparing the results of the case studies conducted at each laboratory to each other allows for the analysis as to what effect an operationally focused user versus a weapon system focused user has on the transition process of environmental technologies. Through this analysis, the third research objective can be achieved.

### **Limitations**

Possible limitations are introduced at different phases of the research project. In the design of the questionnaire, bias could be introduced since the questions were generated based on research discussed in the literature review, which may not have been a completely exhaustive review. The limited number of cases reduce the generalizability of the case studies to the Air Force laboratories as a whole.

In the interview itself, problems could arise because the respondent is required to answer questions, in a limited amount of time, that cover a transition effort that could have taken several years to reach its current point. The effects of this limitation can be minimized by providing each proposed respondent with a copy of the questionnaire in advance of the interview. The recording device could pose a distraction to the respondent, but the effects should be minimized by giving the respondent the option not to use the tape recorder.

### **Summary**

With the data collected, the analysis provides a comprehensive narrative of the transition efforts at WL and AL. Chapter Four focuses on presenting the results of the data collection and analysis methodologies presented in this chapter. The remainder of the thesis provides conclusions as to the similarities and differences experienced in transitioning environmental technologies versus the transition of technology in general and how the developer-user relationship effects the transition process. Chapter Five concludes with a solid framework from which future research should be drawn.

## **IV. Analysis and Results**

### **Introduction**

The purpose of this chapter is to analyze data collected using the methodology and questionnaire described in Chapter Three and Appendix A, respectively. Data were collected for five separate transition projects, two from Wright Laboratory (WL) and three from Armstrong Laboratory (AL), and were collected with the goal of addressing the research objectives. These research objectives were previously presented in Chapter One, and are restated here for convenience:

1. Identify, through analysis of current literature, the potential barriers to, and bridges that aid in the execution of, a successful technology transition.
2. Identify specific potential barriers impeding the successful transition of environmental technologies in the Air Force; i.e. which barriers are unique to environmental technologies and which barriers are common to those found in the literature.
3. Analyze the differences between transitioning environmental technologies from laboratory to major weapon system programs, through System Program Offices (SPOs), and from laboratory to operational field organizations and determine the relative success of these types of transitions.

The first section of this chapter provides a comprehensive narrative describing the transition specifics for each of the five transitions. For each technology, a brief introduction is provided, with the purpose of giving the reader a basic understanding of the technology and the environmental implications involved. A detailed discussion follows the introduction which focuses on the data gathered from personal interviews. In order to provide a clear delineation between the developing organization's and the using

organization's perspective, data collected from the developing organization's transition point of contact's (POC) perspective will be presented first followed by data collected from the using organization's transition POC.

Following the presentation of the five case studies, a chapter summary highlights the key findings from the five transition programs. Common themes from the comparison and contrasting of the cases are discussed, and are directed towards addressing the research objectives.

### **Wright Laboratory Technology Transition Cases**

**Maintenance-Free Advanced Aircraft Battery.** Currently, vented nickel cadmium (NiCd) batteries are used for main-battery applications in a majority of the aircraft in the Air Force inventory. The purpose of the main battery in an aircraft is to provide emergency backup of essential equipment and flight critical equipment, auxiliary power for maintenance activities, and to provide starting power for auxiliary power units and engines.

In order to keep the batteries fully charged, they require a *topping-off* charge, or overcharge. This overcharge process results in the conversion of water into a gaseous form of oxygen and hydrogen. Taken over several charge and discharge cycles, these gases escape from the battery cell vent caps, resulting in water usage. This eventually leads to the requirement for a maintenance action to keep the battery in proper working order. It is these maintenance activities that lead to the requirement to dispose of the hazardous wastes generated by the use of cadmium and other heavy metals.

The development effort undertaken by WL builds upon battery technologies previously developed for spacecraft: a battery that does not require maintenance, and makes the necessary modifications to incorporate this space technology into aircraft applications. This effort has led to the development of a sealed NiCd battery that is maintenance-free for up to a 20-year period of operations. Along with the long maintenance-free period of operation, there are two additional key benefits realized from this program. First, the extension in battery life will lead to a significant reduction in the disposal requirements for the hazardous wastes found in cadmium. Secondly, the eventual implementation of this technology will reduce maintenance costs to the Air Force by a significant amount, estimated at \$500 million over a 20-year period. The maintenance-free battery is categorized as an avoidance technology.

**Findings: Developing Organization Perspective.** The developing organization, WL's Aerospace Power Division, is responsible for the development and eventual transition of new technologies aimed at improving such power production areas as semiconductors, batteries, plasma, thermal, and electromagnetics. The developing agency's transition POC for the maintenance-free battery has been employed with the Federal Government for seventeen years, all of them as a Civil Service employee. For all those seventeen years, he has been assigned to WL developing new battery technologies. Due in large part to his long tenure in the battery development field, he considers himself very familiar with the technology being transitioned in this program. He has four years of technology transition experience with WL, all of which has come from his participation in this specific development and transition effort.

While he is not currently involved with other transition programs within the lab, his position as Program Manager for Battery Development requires a portion of his time be spent addressing other issues within the department. These additional responsibilities include managing twelve separate battery development projects and briefing visitors and decision makers on these new battery technologies. Even though program management is involved in his daily responsibilities, the transition POC classifies his position as one that combines engineering and program management, with a focus on engineering.

The transition POC believes this transition effort is one in which the technology has been *pushed* from the lab to the user. As mentioned in the introduction, this technology has been used on spacecraft for some time. Laboratory engineers were the first to identify the potential for adapting this technology for use on aircraft. At that time, the list of potential users were only limited by the number of aircraft in the Air Force inventory currently using vented NiCd batteries. The possibilities for this adapted technology was briefed to potential users from Air Combat Command (ACC) and Air Mobility Command (AMC), and it was at this point that a potential test-platform user was identified.

The E-8 Joint STARS program was identified as the first potential receiver of the maintenance-free battery technology. The F-16 SPO has also expressed interest in the technology, but will wait until the technology has been implemented on the E-8 aircraft and has been thoroughly flight tested before making a commitment to modify the current fleet of F-16s.

Due in large part to the technology being pushed from the lab to the user, no Mission Need Statement was generated for the maintenance-free battery program. The



technology was essentially advertised at Senior Engineering Technology Assessment Review (SENTAR) briefings and other program reviews. The transition POC also expressed the importance of using established networks to get information out to potential users. Strong networks were possible with this transition program because of the limited number of people involved with military-battery development.

Once it was determined there was a potential user for the technology, the developing organization began to focus attention on planning for a successful transition of the technology to the identified user. An Emerging Technology Summary (ETS) document was developed to chart the path this development and transition effort would follow. The ETS also established a formal relationship between the lab and the Joint STARS SPO.

Within the transition process itself, the transition POC identified several key formal elements that were previously identified in the literature review. Of the formal elements listed in the questionnaire, the transition POC believes identifying someone within the lab to champion the technology was the most important formal element found in the transition process. The previous lead engineer for this development effort was instrumental in marketing the program in the early phases of development. The transition POC also noted that the thorough documentation of the development of the technology (not much documentation regarding the specifics of the transition of the technology) was an important formal element. Finally he identified the importance of establishing a specific project, to include a team of people, to manage the development and transition of the technology as the last formal element.

In addition to the formal elements, the transition POC also identified several of the informal elements discussed in the questionnaire as important to this transition effort. First, a good working relationship was established between the lab and the Joint STARS program. Again, with a small community of people, like that found in military battery development, the transition POC viewed the relationship between the lab and the SPO as the most important informal element. Also, because of the tight network of people involved with military batteries, credibility between the parties involved in the transition process were important to the transition POC. Finally, the transition POC believes the willingness of the parties involved in the transition to communicate and share ideas and information, even when accomplished through informal avenues, to be the final key informal element.

**Barriers: Developing Organization Perspective.** The transition POC defined a successful technology transition program as one in which the user actually takes receipt of the technology developed by the lab and implements it into the weapon system. Under this definition, the maintenance-free battery technology has not reached this final point of success. Once the Joint STARS program, or any other potential user, implements the technology, the transition effort will be considered a complete success from the transition POC's perspective. At this time, the Joint STARS SPO has not programmed funds for the modifications necessary for integration of the maintenance-free batteries.

The transition POC identified several barriers that were present in this transition effort. The most crucial barrier has been the effect of a diminishing research and development (R&D) budget on the technology development and transition effort. The

transition POC believes the program itself would not have survived using only research funds from within the laboratory. Additional funds from other sources, including the AFMC Science and Technology office, were key to the successful development of the maintenance-free battery. The funds provided by the Science and Technology office were provided due to the environmental benefits to be realized from this new technology.

Without additional funding sources for this development project, it is possible the technology never would have reached a development stage where it could be transitioned.

An additional barrier related to the barrier discussed previously was identified by the transition POC. In the case of this technology, the using organization was very interested in obtaining actual data on how much money would be saved by reducing the hazardous waste disposal frequency. The concern is that the developer does not have the additional funds needed to conduct the operational-type tests that can answer these types of questions. Without additional funds to conduct these types of tests, the laboratory is unable to provide the Joint STARS program office with an estimate of the potential environmental savings to be realized.

**Bridges: Developing Organization Perspective.** The transition POC identified several bridges found in the questionnaire that were present in this transition effort. Identified as the key bridge in this transition was the use of newsletters, meetings, training sessions, consulting activities, and advertising to disseminate information regarding the program. From the transition POC's standpoint, meetings were the most important of these activities. It was also noted that the Internet/World Wide Web was being used more by WL to advertise their technology development programs. Recently, several calls for

consulting inquiries have come from potential users who found the technology on the Internet/World Wide Web. These advertising methods have made it easier for other potential users to become educated on the maintenance-free battery technology.

A second bridge identified by the transition POC as key to the success of this program was the establishment of a strong lab-user relationship early in the program. This early establishment of a relationship allowed lab personnel to focus on the specific needs of the user, since a forum had been established for each party to voice concerns.

Strong leadership within WL was also an additional bridge in the transition effort of the maintenance-free battery technology. WL leaders have avenues not available to the working-level program managers to seek funding and to identify and establish relationships with potential users.

Another important element in this transition effort was the existence of a strong external environment. The transition POC believes the publicity and the importance of environmental issues within the Air Force, and the nation as a whole, helped the program progress, and helped keep it funded.

The final bridge important to the transition of this technology is the spirit and willingness of the lab to explore new ideas. The transition POC strongly believes the development and eventual transition of this and future technologies are vital to the survival of WL. Technologies must have potential for both a successful development and a successful transition to a prior identified user.

**Findings: Using Organization Perspective.** Within the Aeronautical System Center, a single SPO is chartered with the management of non-developmental aircraft

systems. Included with these non-developmental systems are the E-8 Joint STARS, Airborne Warning and Control (AWAC), and the C-21 aircraft systems. The using organization's transition POC has been employed with the Federal Government for 27 years, all of them as a Civil Service employee. During the last two years, the transition POC has been assigned to the non-developmental aircraft SPO.

The transition POC's familiarity with the maintenance-free battery technology is based on his two years of experience working with the Joint STARS SPO. He has two years of technology transition experience with the SPO, all of which has come from his participation in the transition of the maintenance-free battery. His position as Technical Focal Point for Power Requirements requires his time be divided between this transition project and other areas to include oversight of technical issues with the avionics system and the flight management system. The transition POC classifies his position as an engineer, responsible for the review of technical proposals and technical plans.

The transition POC agrees with the developing organization transition POC's view that the technology was pushed from the lab to the user. Essentially, the Joint STARS program was unaware of the available technology and the benefits of using a maintenance-free battery until the information was briefed to all potential users.

At this point in the transition process, the Joint STARS SPO has not developed a plan to guide the receipt of the technology. The transition POC believes that a plan has not been developed due to the future uncertainty in the funding required to test, modify, and eventually implement the new maintenance-free batteries into the Joint STARS platform.

Within the transition process itself, the transition POC identified several key formal elements that were previously discussed in the literature review. Of the formal elements listed in the questionnaire, the transition POC identified with the importance of identifying a champion to push the technology, even though a champion has not been identified at the SPO. In addition, the transition POC believes it was important to be kept up to date of progress made in the development of the new maintenance-free battery, especially as to when the test batteries would be available.

In addition to the formal elements, the transition POC identified several of the informal elements as being considered important to this transition effort. First, the transition POC believes the relationship between the lab and the Joint-STARS program office, while not vital to the successful transition of the technology, was important to a certain extent. It was not considered vital from the transition POC's perspective because the maintenance-free battery development was progressing smoothly. Essentially, there were other issues with the aircraft design that required more attention. The transition POC believes this *silent partner* relationship works well because of the credibility of the two parties involved.

**Barriers: Using Organization Perspective.** The transition POC defines a successful technology transition program as one in which the lab provides the user with a product that can be integrated into the weapon system with minimum risk. Using this definition, the using organization's transition POC agrees with the developing organization's transition POC's view that the maintenance-free battery technology has not yet reached this final level of success. The transition POC is optimistic this transition

effort has the potential to be successful once the test batteries have been operationally tested, and the funds made available to modify the aircraft as necessary.

The transition POC identified several barriers found in the questionnaire that were present in this transition effort. First, the transition POC believes technical risks were a barrier to this transition effort. The risks originated not so much from the development of the maintenance-free battery, but with the eventual integration of the new batteries with the existing aircraft. The major concern being the modifications in the wiring design that will be required to integrate the new batteries.

Another key barrier identified by the transition POC was a lack of funds for the program. The concern is not whether there exist sufficient funds to develop the battery, but whether funds will be available to fully test the new technology and make the necessary modifications to the aircraft. If additional funds are not programmed and appropriated, it is likely that the maintenance-free battery technology will not be implemented into the Joint STARS aircraft.

Finally, the lack of awareness of the new technology at the decision maker level was identified as a barrier to a successful transition effort. The Joint STARS program is managed from Hanscom AFB, with personnel stationed at Wright-Patterson AFB serving as technical experts for specific issues concerning the aircraft itself. The technical experts are aware of the technology and the modifications necessary to eventually implement it into the weapon system platform. The concern expressed by the transition POC is that the decision makers at Hanscom AFB are overly optimistic with regards to the modifications necessary to implement the batteries. While Smilor and Gibson identify distance as a

barrier to the transition process, the transition POC believes the distance between the program managers at Hanscom AFB and the technical experts at Wright-Patterson AFB does not present a barrier in this case.

**Bridges: Using Organization Perspective.** After reviewing the questionnaire, and discussing the bridges discovered in previous research, the transition POC believes that none of the bridges listed had an important impact on this transition effort. A summary of barriers and bridges found in the transition of the maintenance-free battery is provided in Table 4.1. Within the table, each barrier and bridge will be prefaced by a bold, capital *U*, *D*, or both. A *U* signifies the barrier or bridge was identified by the using organization's transition POC. A *D* signifies that the barrier or bridge was identified by the developing organization's transition POC. Finally, if a *U* and a *D* are present, then both transition POCs identified the barrier or bridge. This identification system will be used in the remainder of the cases. In addition, if the barrier or bridge is followed by a bold asterisk, the bridge or barrier is discussed in the Key Findings section of this chapter as a barrier or bridge unique to the transition of environmental technologies.



TABLE 4.1

SUMMARY OF BARRIERS AND BRIDGES TO TRANSITION OF  
MAINTENANCE-FREE BATTERY

<b><u>Barriers</u></b>	
<b>Technical</b>	
(U) Technical risk	
<b>Regulatory</b>	
(D, U) Diminishing budget for test and modifications	(D) Diminishing R&D budget
<b>People</b>	
(U) Lack of awareness of the new technology	
<b><u>Bridges</u></b>	
<b>General</b>	
(D) Newsletters, meetings, training sessions, consulting, and advertising	(D, U) Developing lab-user relationship early in development/transition process
(D) Strong leadership	(D) Strong external environment
(D, U) Identifying technology champion	(D) Spirit and willingness to explore and learn
(D, U) Technical ability of transition POCs	
<b>Formal</b>	
(D) Thorough documentation of development effort	(D) Establishment of a specific project
(U) Proper distribution of information	
<b>Informal</b>	
(D) Willingness to communicate ideas and information	(D) Credibility of the parties involved

**Halon Replacement for Aviation Systems.** The objective of this development and transition program was to determine a replacement for halon as a fire extinguishing agent for use in military, and potentially, civilian aircraft. Initially, twelve potential replacement agents, which had the characteristics necessary to extinguish on-board fires, were selected by the Air Force. All twelve were laboratory-tested by the National Institute of Standards and Technology (NIST) to determine compatibility with aircraft systems, operating personnel, and the environment. Based on their testing, NIST recommended three agents to the Air Force for full-scale testing. Concurrent with testing being conducted by NIST, the Vehicle Subsystems Division of WL conducted basic fire parameter tests. Beginning in FY94, the three agents selected for full-scale testing were examined under realistic operational and environmental conditions. By the end of FY94, the most qualified of these three agents was identified. The selection was based on numerous criteria, including the weight and volume required to extinguish fires, affordability, logistics, toxicity, and maintenance requirements. Further testing and development of the design equations were accomplished in FY95.

The chemical ultimately selected by this process as the replacement for halon is known as HFC-125. It can be used in all military and commercial aircraft as a fire extinguishing agent for both engine nacelle and dry bay applications. HFC-125 provides for an environmentally-safe chemical while protecting the lives and property at the same level as halon. HFC-125 is also comparable to halon in other areas such as producability, supportability, affordability, and safety. The halon replacement, HFC-125, is categorized as an avoidance technology.

**Findings: Developing Organization Perspective.** The transition POC for the Vehicle Subsystems Division of WL has been employed by the Federal Government for four years, all of them as an active duty Air Force officer. He has been assigned to WL in this position for the last nine months. He has a solid understanding of the technology involved; not so much the chemistry involved, rather an understanding of the relevance of the transition effort and the history of the development and transition program. His technology transition experience centers on the last nine months working the halon replacement program at WL. His responsibilities in this transition effort include finalizing the transition, preparing all required program documents for WL and SENTAR approval, and preparing the final program briefing. While he is not currently involved with other transition programs within the lab, his position requires time be divided between managing the transition effort and providing engineering support, leading engineering reviews, and conducting factor of safety analyses for the program. His position is officially coded for an engineer; however, the transition POC classifies his position as a combination between that of an engineer and a program manager.

The transition POC views this transition effort as one in which the technology was pulled from the lab. Instead of the user coming to the lab with a requirement, the pull has come from a change in the regulations governing the use of halon. The Montreal Protocol is a treaty that was signed by 43 nations who met in Montreal, Canada in September 1987 to discuss the effects of halon and other ozone depleting chemicals. The Protocol established policy banning the production of halon 1301 and the use of existing stockpiles for new fire suppression systems. Currently, the F-22 is the only aircraft system that has

yet to enter the full-scale production phase of its acquisition lifecycle. With halon 1301 restricted from use in new systems, the F-22 instantly became a user with a need.

Therefore, the technology is being pulled by this new requirement placed upon the user by policy established in the Montreal Protocol.

Even though the F-22 is the only aircraft system that will require the use of HFC-125, all new aircraft and other military systems that have a need for fire suppression will be required to implement an alternative agent before they enter full-scale production. Other aircraft systems currently in the Air Force inventory have expressed an interest in HFC-125, but coupled with the fact there is no requirement for systems currently using halon to replace it, and the high costs associated with modifying the weapon platform, it is highly unlikely that other aircraft systems will make the switch to HFC-125 until they are forced to by regulation.

Regarding the transition process, a formal strategy was developed by the lab. It was intended to be used as a *road map* to guide the development and transition process. A key element in this plan was the development of a strict milestone chart. This was important because the Montreal Protocol established regulatory dates when halon 1301 would be restricted from production and restricted from use in new systems. This plan constituted a commitment between the user and the lab that defined how the technology would eventually be transitioned.

Within this transition process, the transition POC identified several formal elements that were discussed in Chapter Two. Of the formal elements listed in the questionnaire, the establishment of a champion for the program was most important from the transition

POC's perspective. A key characteristic of the champion was his ability to combine a firm technical understanding of the technology, including a chemistry perspective, with an ability to market the technology. Another formal element identified as important to the transition process was the thorough documentation of the development and transition effort.

In addition to the formal elements, the transition POC also identified with most of the informal elements listed in the questionnaire. First, a working relationship between two credible parties, WL and the F-22 SPO, was identified as an important informal element. The transition POC believes this is partly due to the nature of the new regulations governing halon use. The F-22 SPO essentially had no option but to implement a replacement agent into their aircraft design. Therefore, they were very supportive of the development effort undertaken by WL. Because of this credible relationship, the transition POC believes both parties were more willing to communicate and share information. As an example, the lab has made every effort to ensure the F-22 SPO is represented at all technical reviews and program meetings.

In addition to establishing a working relationship and involving credible parties, the transition POC identified the use of reward mechanisms as a key informal element found in this transition effort. The transition of HFC-125 was selected for the Lt Gen Thomas Ferguson Award for Excellence in Technology Transition. From the transition POC's perspective, the people involved with the development and transition effort were also rewarded with the pride that came from being involved with a successful program, that met both the needs of the user, and benefited the environment.

**Barriers: Developing Organization Perspective.** The transition POC defines a successful transition as one where the lab develops a technology that meets the need of the user and minimizes the risk in implementing it into their weapon system. It is the lab's responsibility to create an atmosphere that fosters transition of this technology by documenting and presenting methods by which the technology can be used. It is then up to the user to decide whether or not to incorporate the developed technology. With respect to this definition, the transition of halon replacement agent HFC-125 was successful.

Of the barriers identified in the questionnaire, the transition POC believes that all of them had a minimal effect in hindering the transition process. Instead, he identified three barriers not listed in the questionnaire which were present in this transition project.

First, the development and transition program was under a tight schedule constraint. Even though it will be several years before the F-22 reaches full-scale production, the Montreal Protocol set specific dates when the use of halon 1301 would no longer be allowed on new systems. This forced the lab to accelerate their development schedule to ensure a replacement was found in order to comply with new regulations.

Another barrier identified was the two-year rotation of military personnel within the lab. Many of the key personnel involved with this transition effort were active duty military officers. This posed several problems. First, the rotation policy made it difficult for military personnel to stay current with progress made in the development of the technology. Secondly, it forced the Civil Service personnel in the lab to establish and maintain many of the key relationships with the user.

A final barrier discussed by the transition POC was the oversight of environmental protection agencies. This oversight involved agencies from all levels: federal, state, and base-level. Most of the oversight was generated due to the nature of the test program, which involved the use of large amounts of halon. The potential existed for this barrier to delay many phases of the test program had WL not been able to respond sufficiently to the concerns of the environmental protection agencies.

**Bridges: Developing Organization Perspective.** The transition POC identified several bridges that were present in the transition of HFC-125. First, developing a lab-user partnership and involving the user early was an important bridge.

Secondly, the strong external environment that drove this development effort was key to the success of this program. With the policy set by the Montreal Protocol, there was no option but to develop a replacement agent. Had no such regulation been established, it is likely the F-22 would be designed to use existing halon technology, and HFC-125 would have never been developed.

Finally, there was a spirit of teamwork and success generated from this program. The spirit came as a result of the pride generated by lab personnel involved in the development and transition of HFC-125, and the recognition of the program. It was this spirit that helped keep people motivated and focused on the goal of developing and transitioning a suitable replacement agent.

**Findings: Using Organization Perspective.** As mentioned above, the F-22 program had been identified as an eventual user of the halon replacement, HFC-125. The

F-22 SPO is responsible for managing the development and eventual production of the F-22 aircraft.

The using organization's transition POC has been employed with the Federal Government for ten years, all of which have been as a Civil Service member. Of those ten years, he has been assigned to the F-22 SPO for the last four years. His technology transition experience covers five years, with four years coming from his current position, and one year from an assignment outside the F-22 SPO. As the Integrated Product Team (IPT) lead for the Fire Suppression System, he is very familiar with the technology and issues involved with this transition effort. In addition to his responsibilities as the lead for the Fire Suppression System IPT, he is also the lead for the Fuel System IPT. Because of these management responsibilities, the transition POC classifies his position as a combination between an engineer and a program manager.

The user's transition POC disagrees with the belief of the developer's transition POC that the technology is being pulled by the regulations and the user; and instead believes the technology is being pushed from the lab. This is based on the user's transition POC perspective that it was WL who first approached the F-22 SPO and discussed the results and implications of the Montreal Protocol.

With regard to the transition process, the F-22 SPO has not developed a plan to guide the transition and implementation of the replacement agent. The transition POC cited two reasons why no plan has been developed. First, the transition POC saw the program as being pushed from the lab, and therefore the lab should be responsible for planning the transition. Secondly, the transition POC was assured that there would be a



replacement agent developed, and the F-22 program had other issues that demanded more attention.

Within the transition process itself, the transition POC identified several key formal elements that were present in the transition of HFC-125. Perhaps the most important formal element was the champion at the lab who pushed and kept the F-22 SPO aware of the development progress on a regular basis. Based on the champion's commitment, the transition POC felt assured that the development effort would lead to a successful technology that could be transitioned to the F-22. Also, because the transition POC had instilled such a level of trust in the lab to complete a successful development, it was important to receive updates and other information regarding progress towards HFC-125.

In an informal manner, the transition POC found the relationship established between the lab and the user, and the credibility of the two parties involved to be an important informal element in the transition process. This informal element helped improve communications between the developing and using organizations, and to increase the exchange of ideas and information.

**Barriers: Using Organization Perspective.** The transition POC defined a successful transition program as one where the user receives a technology or product that can be implemented to the weapon system within cost, schedule, and performance constraints. Even though this technology has not yet been implemented by the F-22, the transition POC classifies this transition effort as successful because HFC-125 meets the needs of the weapon system, and does so within the constraints discussed.

Two barriers were identified by the transition POC as posing problems in the transition of HFC-125. First, technical risk was a concern to the F-22 SPO. The concern was not whether a replacement agent could be developed. Instead, the concern was based on whether the agent that was eventually developed would be an optimal replacement from a cost, schedule, and performance standpoint. Had the proposed replacement failed to meet the needs of the F-22 within the cost, schedule, and performance constraints, it is likely HFC-125 would have been shelved for future improvements, or a new replacement agent would have been developed.

Secondly, fear about leadership's ability to handle the new technology was identified as a barrier to this transition effort. Decision makers within the SPO did not understand that HFC-125 could not be implemented into the aircraft without making some modifications to the aircraft design. HFC-125 is approximately two-and-a-half times greater in volume, and about two times greater in weight, than halon.

**Bridges: Using Organization Perspective.** The transition POC identified two bridges listed in the questionnaire that aided the transition of HFC-125. First, from the transition POC's perspective, the establishment of a lab-user partnership and the involvement of the F-22 SPO early in the development effort were the most important bridges. By involving the F-22 SPO early in the development process, the SPO was able to voice their concerns on such issues as cost, schedule, and performance constraints. Secondly, the strong external environment, fueled by a general heightened awareness of environmental issues, increased the transition POC's awareness and increased his desire to

make the transition of HFC-125 a success. A summary of barriers and bridges found in the transition of the replacement agent for halon, HFC-125, is provided in Table 4.2.

TABLE 4.2

SUMMARY OF BARRIERS AND BRIDGES TO TRANSITION OF  
REPLACEMENT AGENT FOR HALON, HFC-125

<u>Barriers</u>	
<b>Technical</b>	
(U) Technical risk	(D) Tight schedule constraints
<b>Regulatory</b>	
(D) Regulatory agency oversight *	
<b>People</b>	
(D) Rotation schedule of military personnel within the lab	(U) Fear about leadership's ability to handle new technology
<u>Bridges</u>	
<b>General</b>	
(D, U) Strong external environment	(D, U) Developing lab-user partnerships and involving the user early
(D) Spirit and willingness to explore and learn	(D, U) Identifying technology champion
(D, U) Technical ability of transition POCs	
<b>Formal</b>	
(D) Thorough documentation of the program	(U) Proper distribution of information
<b>Informal</b>	
(D) Willingness to communicate ideas and information	(D) Reward mechanisms

## **Armstrong Laboratory Technology Transition Cases**

**Rapid Optical Screening Tool (ROST)**. Recent estimates show the cost of characterizing a hazardous waste site using today's technology to be approximately 25 to 30 percent of the total cleanup and remediation costs. To help reduce this cost, a research and development program was initiated with the involvement of the Environics Directorate of Armstrong Laboratory (AL/EQ) and the Human Systems Center (HSC). The goal was to integrate a laser spectrometer with fiber optics and a cone penetrometer to provide the required *snapshot* needed for rapid characterization of subsurface conditions; the end result being the ROST system. ROST uses laser induced fluorescence (LIF) to detect the presence and absence of compounds such as petroleum fuels. The ROST system was designed to provide rapid sampling and real-time, relatively low cost screening level analysis of the physical and chemical characteristics of subsurface soil. The use of ROST technology will result in substantial savings in costs associated with characterization, monitoring, and remediation of hazardous waste sites. The ROST system is categorized as a monitoring and assessment technology.

The data and findings for this case study consists solely of the developing organization's perspective. This is due primarily to the fact that any Air Force installation is considered a potential user for this technology, and thus presented a difficult obstacle in finding a single user whose particular site characterization situation represented a majority of potential users.

**Findings: Developing Organization Perspective**. The developing organization's transition POC has been employed with the Federal Government for eleven years, all of

them as a Civil Service employee. The transition POC has been assigned to AL for the last nine years and six months. He has been involved with the development and transition of the ROST system since program origination, and therefore considers himself very familiar with the technology. During his tenure with AL, the transition POC has been ever increasingly involved with technology transition. Due to the nature of his position as Technical Area Manager for Site Characterization and Monitoring, he is currently managing several other projects that are also being reviewed for transition from the lab. In addition to his responsibilities of managing these technology transition efforts, he is responsible for other projects dealing with site characterization, monitoring, and sensor development. He also serves as Division Chief when required to by the Chief's absence, briefs program status to parties both within and outside the lab, and spends a portion of his time working project funding issues. Even though his position is classified as an engineer, the transition POC personally feels his position is more focused on program management.

The transition POC believes this transition effort has been one in which the technology has been pushed from the lab to the users. When the transition POC was first assigned to AL, he was presented with information regarding the use of fiber optics in sensor applications. However, the division was focused on site remediation and remediation technology at the time. His interest in the potential for fiber optics was sparked by his belief that the first step to a successful cleanup effort was the proper characterization of the hazardous waste site. This search for additional applications of fiber optic sensors eventually led to the development of the ROST program.

As previously mentioned, any Air Force installation is considered a potential user for the site characterization technology. However, the site characterization device is not designed to be permanently stationed at Air Force installations, rather the installation would either contract with a local Architectural and Engineering (A&E) firm, or work through AFCEE to locate an agency to conduct the characterization service. For example, AFCEE works with the Kansas City district of the Army Corps of Engineers, which has the equipment to conduct the site characterization for the requesting installation.

To aid the development and transition process, the laboratory implemented a formal strategy that provided a method for tracking progress of the development effort. Within this transition process, the transition POC identified several formal elements present in the transition of the ROST system. The establishment of a champion for the technology was identified as the most important formal element. The transition POC played a key role in early marketing efforts of the program, and ensured funds would be available for complete development. In addition, the thorough documentation of the development effort and the proper distribution of this information through presentations and demonstrations were identified as additional formal elements important to the transition process.

Combined with the formal elements, the transition POC identified several informal elements that were an integral part of the transition process. First, a good working relationship was established and maintained with AFCEE, HSC, and base-level end-users throughout the development and transition of the ROST technology. These relationships were key to the transition process because of the number of players involved with the

transition; AFCEE, HSC, and base-level end-users. Also, reward mechanisms were identified as an important element in the transition process. The reward mechanisms were based on recognition the program received due to its success.

**Barriers: Developing Organization Perspective.** The transition POC defined a successful technology transition program as one in which the technology is developed and transitioned past the 6.3 (advanced development) level. Based on this definition, the transition of the ROST system is classified as a successful transition effort. It should be noted that the ROST technology, while successfully transitioned past the 6.3 research and development stage, has been successfully transitioned to multiple users in the field.

The transition POC experienced similar hurdles in the transition of the ROST system as those listed in the questionnaire. First, technical risks presented a barrier during the early stages of the development program. The program was based on exploratory-type research that had been conducted on the use of fiber optics as sensors. The concern was that further research might not lead to the development of a useful end-item.

A second barrier that concerned the transition POC was the lack of awareness of the ROST program among potential users. The transition POC found that regardless of the extent the program was advertised, demonstrated, and presented at meetings, there were still users who were unaware of the site characterization potential of the ROST system. This barrier could have eventually led to a situation where an environmental technology was under-utilized.

Finally, regulatory barriers were identified as a barrier in the ROST system transition effort. During the testing phase of the program, potential users had voiced

concerns regarding the acceptance by environmental regulators of the ROST site characterization results. If an environmental technology is not accepted by the regulatory agencies, then the base-level user would be forced to find an alternative method to solve its problem. Demonstrations and the establishment of case studies were used to alleviate this barrier as the test program progressed.

**Bridges: Developing Organization Perspective.** The transition POC identified several bridges from the questionnaire that were also present in the transition of the ROST system. Providing test facilities and support to potential users of the ROST system was identified as the key bridge in this transition. Many bases were eager to be involved with the test phase of the development program. The transition POC believes that taking the technology to a potential user's installation and demonstrating its potential for site characterization, the user is more inclined to accept the technology as a viable characterization method.

Another bridge that aided in the acceptance of the technology was the recommendations of a third-party organization, in this case the Environmental Protection Agency (EPA). The ROST system was featured and evaluated under the EPA's Superfund Innovative Technology Evaluation (SITE) program. This evaluation program provided additional assurance to the potential user that the ROST system was an acceptable method for characterizing hazardous waste sites. A summary of barriers and bridges found in the transition of the Rapid Optical Screening Tool (ROST) is provided in Table 4.3.



TABLE 4.3

SUMMARY OF BARRIERS AND BRIDGES TO TRANSITION OF  
THE ROST SYSTEM

<u>Barriers</u>	
<b>Technical</b> (D) Technical Risk	<b>Regulatory</b> (D) Regulatory agency oversight *
<b>People</b> (D) Lack of awareness of new technology	<b>Other</b> (D) Difficulty in clearly defining end-user *
<u>Bridges</u>	
<b>General</b> (D) Developing lab-user partnerships and involving the user early	(D) Providing test facilities and support to potential technology users
(D) Recommendations of third-party organizations	(D) Identifying technology champion
(D) Technical ability of transition POC	(D) Demonstrating technology to end-user*
<b>Formal</b> (D) Thorough documentation of the program	(D) Proper distribution of information
<b>Informal</b> (D) Reward mechanisms	

**Bioventing Process.** Bioventing is the process of delivering oxygen by forced air movement to contaminated, unsaturated soils in order to stimulate biodegradation of the contaminants. Bioventing employs low air flow rates that provide only the necessary amount of oxygen for biodegradation. While bioventing is related to the process of soil vacuum extraction (SVE), the primary objectives of these two bioremediation

technologies are significantly different. SVE is designed and operated to maximize the volatilization of low-molecular-weight compounds, with some biodegradation occurring. In contrast, bioventing is designed to maximize biodegradation of aerobically biodegradable compounds (such as JP-4), regardless of their molecular weight, with some volatilization occurring. The major distinction between the two technologies is that the objective of SVE is to optimize removal by volatilization, while bioventing optimizes biodegradation while minimizing volatilization and capital and utility costs. The reduction in capital and utility costs is due to the fact that the bioventing process does not require any off-gas treatment equipment.

AL's Environics Directorate began a research and development program in 1988. AFCEE became involved with the development and demonstration program in 1991. Development and demonstration efforts eventually included field studies at over 120 sites, conducted at over 50 military installations. The results from these bioventing research and development efforts led to the publication of a two-volume manual on the use of bioventing technology. The manual provides details on bioventing principles, site characterization, field treatability studies, system design, installation and operation, process monitoring, and site closure. The bioventing process is categorized as a remediation technology.

**Findings: Developing Organization Perspective.** The developing organization's transition POC has been employed by the Federal Government for twelve years; the first nine years as an active duty Air Force officer and last three as a Civil Service employee. The transition POC has been assigned to AL for the past seven years. Due in large part to

her four year tenure as Technical Area Manager for Biotechnologies, and her involvement with the bioventing process since its inception, the transition POC considers herself very familiar with the technology. She has five years of transition experience with AL, most of which has come from her participation in the development and transition of the bioventing process.

As the Technical Area Manager for Biotechnologies, the transition POC is responsible for the management and oversight of five other biotechnology projects, management of three other personnel and their projects, review of technical proposals, contract preparation, and technical oversight. Her responsibilities will increase with the projected loss of one of her colleagues later this year. In addition to her responsibilities to AL, she also serves as the U.S. representative for water treatment issues on a German data exchange program. To properly manage these responsibilities, she spends approximately half the year on the road meeting with technology users, attending conferences, and marketing developmental technologies. The transition POC classifies her position as one which combines both engineering and program management skills.

The transition POC believes the transition of the bioventing process was driven by a pull from the users at operational installations. It is conservative to estimate that a majority of military installations have some level of soil contamination that needs to be remediated. No formal need statement was submitted by the user, instead, AL and AFCEE initiated a program to develop and demonstrate the capabilities of the bioventing process. This demonstration process involved establishing a short-term (1 year) pilot study program. Questionnaires were sent to all Air Force installations explaining the

criteria that would have to be met in order to participate in the program. This demonstration process became known as the Bioventing Initiative, and initially involved 50 sites. As more funding became available, the Initiative expanded to include more than 120 sites at more than 50 separate installations.

The transition POC identified the transition of the bioventing process as a unique case in that the key advocate for the users at the base-level, in this case AFCEE, was also instrumental in the development of the bioventing process. Because of this, a fairly informal transition strategy was used to transition the technology. To the transition POC's knowledge, the only formal document used to approve the technology development process was a Project Approval Document (PAD). The PAD essentially explains the development goals of the project and ensures funding has been provided to complete development. The PAD is approved by the AL/EQ director. Included in the PAD is a short section that discusses how the technology will eventually be transitioned to the user.

Within the transition process itself, the transition POC identified several formal elements that were previously discussed in Chapter Two. Of the formal elements listed in the questionnaire, the transition POC believes the unique situation of having a key person in the development role also play an instrumental role in championing the program at the user's end of the process was vital to the transition process. In addition to the importance of a champion, the thorough documentation of scientific issues concerning the use and acceptance of the bioventing process was identified as an important formal element.

In addition to the formal elements, the transition POC identified several informal elements present in this transition effort. The transition POC believes the program progressed smoothly because of the relationship and the credibility of the parties involved. Again, this is due in large part to the unique situation discussed earlier.

**Barriers: Developing Organization Perspective.** The transition POC defines a successful technology transition program as one in which the technology developed can be transitioned and implemented by as many users as possible. Using this definition, the bioventing process would be classified as a successful transition effort.

The transition POC identified several barriers from the questionnaire that were also present in this transition effort. Regulatory risk was a barrier that was present early in the development program. Base-level users were concerned that the process would not be approved by environmental regulators in their region as a viable method for spill remediation. This barrier was overcome by implementing the Bioventing Initiative, with test sites in almost all 50 states, including Alaska and Hawaii. By thoroughly documenting each of the cases, assurance was provided to the user that the bioventing process would first of all work, and secondly, would be approved by all regional offices of the EPA.

In addition to the regulatory barriers, the transition POC identified a lack of awareness by the users as a barrier to this transition effort. Again, this barrier was primarily present early in the program. Once the Initiative was expanded to the 120 sites, users quickly became more aware of the potential of the bioventing process. Technology conferences and technical reports published in environmental journals also contributed to the dismissal of this barrier by the end of the demonstration phase.

Finally, the transition POC identified task-saturated personnel as an additional barrier. Due to the magnitude of the demonstration program, and because of the limited number of personnel available to work the development and transition issues, the transition POC believes the bioventing technology was not transitioned to the user as quickly as it could have been.

**Bridges: Developing Organization Perspective.** The transition POC identified several bridges from the questionnaire that were present in the transition of the bioventing process. First, recommendations of third parties was identified as the most important bridge to the success of this transition effort. By demonstrating the technology at a variety of locations and installations, it was almost impossible for environmental regulators not to approve the bioventing process as an acceptable method for site remediation. An official letter was issued by the EPA to all ten regional offices that in effect validated the bioventing process, encouraged users to participate in the demonstration process, and essentially called for the use of bioventing at other Federal and private sites with petroleum product problems.

In addition to gaining approval from the EPA, the transition POC found that providing testing facilities and support to technology users was another bridge present in the bioventing transition program. By demonstrating to the user, without any cost to them, the potential to remediate a spill site at their installation, the developer was able to prove the potential of the technology. Also, by providing a means to demonstrate to the user the potential of the bioventing process, assurance is provided to the user that the technology is an acceptable method for solving their environmental problem.

**Findings: Using Organization Perspective.** The using organization's transition POC has been employed by the Federal Government for ten years and nine months, all of which he has served as an active duty Air Force officer. The transition POC has been assigned to AFCEE for the past three months. Prior to his current assignment, the transition POC was assigned to AFIT as a Doctoral candidate. While the transition POC has only been involved with the bioventing program from a user's perspective for three months, he has extensive experience with the technology. This experience comes from having been assigned to AL's Environics Directorate prior to his Doctoral program. In addition to his three months of technology transition experience with AFCEE, the transition POC has an additional five years of experience from prior assignments. As a project engineer assigned to AFCEE's Technology Transfer Division, the transition POC is also responsible for the management of two additional transition projects. The transition POC classifies his position as an engineer.

Within the transition process itself, the transition POC identified a thorough documentation effort as the key formal element. Items such as work plans, sampling and analysis plans, and closure reports all provided support for the bioventing process. This was important since AFCEE was a key interface between the users at operational Air Force installations, and the development efforts being conducted at AL. The use by AFCEE of a technology selection matrix was also identified as an important formal element in the transition process.

In addition to the formal elements discussed, the transition POC identified three of the informal elements listed in the questionnaire as playing an important role in the

transition of the bioventing process. The establishment of a good working relationship between AL and AFCEE, one in which information and ideas were readily shared between the two parties, was identified as a key informal element. The transition POC believes this type of relationship was possible because of the desire to develop and transition a viable technology, and the credibility and personalities of the people involved with the bioventing process.

**Barriers: Using Organization Perspective.** The transition POC defines a successful technology transition effort as one in which the technology developed is eventually considered in the user's decision making process given they have a need for which the technology can be used. Under this definition, the bioventing process is considered a successful program.

From the barriers listed in the questionnaire, the only barrier identified by the transition POC was a lack of awareness of the new technology. As mentioned earlier, the potential exists for a technology to be under-utilized if some potential users are not educated on the environmental technology's possibilities. The using organization transition POC is in agreement with the developing organization transition POC in how this barrier was overcome.

**Bridges: Using Organization Perspective.** The transition POC identified several bridges from those listed in the questionnaire that were important to the successful transition of the bioventing technology. In addition to these, the transition POC provided several additional bridges that proved valuable to the transition process.



Again, the using organization transition POC is in agreement with the developing organization transition POC regarding the importance of providing a means for the technology to be demonstrated to the user. Also, the transition POC identified a strong external environment as an important bridge. With the increasing interest in remediating spill sites, bioventing was welcomed not only for its ability to remediate past spill sites, but it has also proven to be a very cost effective method.

With regard to the additional bridges identified by the transition POC, demonstrating the technology at as many sites as fiscally and logistically possible, was identified as the most crucial bridge to the successful transition of the bioventing process. According to the transition POC, demonstrations should not be viewed as research, rather they should be thought of as an opportunity to prove to, and market to, the regulators and the potential users the value of the technology. Having confidence in the technology, then aggressively marketing it were also additional bridges present in this transition effort. Believing the bioventing process was a valuable asset provided additional confidence that the technology was capable of meeting the requirements of the end-user. A summary of barriers and bridges found in the transition of the bioventing process is provided in Table 4.4.

**Ion Vapor Deposition (IVD).** Electroplating has been key to the proper operations and maintenance of Air Force weapons systems. The coatings allow aircraft to operate effectively in harsh environments including tropical and desert regions while not suffering the adverse effects of corrosion. While effective, the electroplating process generates toxic materials (cyanide, acid, cadmium, and other heavy metals) that endanger both the

worker and the environment. In addition to the physical threat, the rising costs of treating and disposing of these hazardous wastes has forced the Air Force to look at alternatives to the electroplating process.

TABLE 4.4  
SUMMARY OF BARRIERS AND BRIDGES TO TRANSITION OF  
THE BIOVENTING PROCESS

<b><u>Barriers</u></b>	
<b>Regulatory</b> (D) Regulatory agency oversight *	<b>Other</b> (D) Difficulty in clearly defining end-user *
<b>People</b> (D, U) Lack of awareness of new technology	(D) Task-saturated personnel
<b><u>Bridges</u></b>	
<b>General</b> (D) Recommendations of third-party organizations	(D, U) Developing lab-user partnerships and involving the user early
(U) Aggressive marketing effort	(U) Strong external environment
(U) Use of technology selection matrix	(U) Having confidence in technology
(D, U) Providing test facilities and support to potential technology users	(U) Demonstrating technology to as many potential users as possible *
(D) Identifying technology champion	(D, U) Technical ability of transition POCs
<b>Formal</b> (D, U) Thorough documentation of the program	
<b>Informal</b> (D, U) Credibility of the parties involved	

In 1988, AL began investigating the use of IVD aluminum to replace the electroplating process. The program evolved into a three-phase project, with McDonnell-Douglas contracted to demonstrate and implement into operational status an IVD aluminum coating facility. By February 1992, the technology had progressed to the point that Warner Robins Air Logistics Center (WR-ALC) closed its cadmium plating line. At the end of the third phase in July 1992, the program had been declared a success with the transfer of 123 parts, 100 percent, from the electroplating process to the new IVD aluminum system.

Several important environmental benefits are realized with the use of IVD aluminum coating. First, aluminum is 75 times less toxic than cadmium. The IVD process produces no hazardous waste and, because the process occurs in an enclosed chamber, workers are not exposed to the hazards previously experienced with cadmium.

IVD aluminum also provides better operational results than the cadmium electroplating process. IVD offers better corrosion protection in acidic environments; has a wider useful temperature range (950°F maximum for aluminum); does not embrittle; can be used on titanium and in contact with fuels; and can be used in space applications. The IVD aluminum process is categorized as an avoidance technology.

The data and findings for this case study consists solely of the using organization's perspective. This is due in large part to the fact that personnel involved with the development of the IVD aluminum process were no longer with AL.

**Findings: Using Organization Perspective.** The using organization's transition POC has been employed by the Federal Government for nine years and six months, all of

them assigned to the plating shop at WR-ALC. This shop handles all parts requiring the plating process; including parts from the F-15, C-141, and C-130 aircraft. The transition POC has been involved with the transition of the IVD aluminum process since the program was initiated in 1988, and therefore considers herself very familiar with the IVD process. She is familiar with the technology not just from a process perspective, but also understands the technology from a chemical perspective.

Her responsibilities as both the process/production engineer and facility engineer for the plating shop require her time be split among several other projects. These additional responsibilities include: management of all engineering issues regarding machine operation and maintenance and environmental issues within the plating shop; membership on both the base air and base water committees; membership on both the base hazardous waste and base hazardous materials IPTs; and briefer to all visitors regarding production and environmental issues in the plating shop. The transition POC is also participating in the development of a spraycasting technology designed to replace the use of hard chrome, and the development of a non-chromate conversion coating technology, both of which are future transition efforts. Due in large part to the additional administrative duties, the transition POC classifies her position as one which combines engineering and program management.

The transition POC views this transition effort from the perspective that the technology was pushed from the laboratory to WR-ALC. Even though the disposal of cadmium posed a problem to the plating shop, at no time did WR-ALC generate a mission need statement regarding the need for an innovative technology. Instead, AL came to

WR-ALC and inquired as to their interest in participating in the third phase of the demonstration and implementation project. Final selection of WR-ALC came after a parts survey indicated WR-ALC maintained a representative parts sample.

At this point, a technology representative from McDonnell-Douglas was assigned to assist WR-ALC with equipment installation and process training. This technical representative is still available for phone consulting. The transition POC believes no formal strategy was developed by WR-ALC due to this fact that the technology was pushed from AL. The transition POC's initial involvement with AL regarding the technology was concerning facility modifications needed to install the IVD equipment. As the transition progressed, WR-ALC had additional inputs with the technology representative regarding the methods that would be used to instruct workers on the IVD process.

Within the transition process itself, the transition POC identified several formal elements discussed in the questionnaire that were present in this transition effort. The establishment of a champion for the program was most important from the transition POC's perspective. The champion's role in this transition effort was not to ensure the technology would reach the development stage where it could be transitioned. Instead, his role was to make the transition a smooth process and motivate WR-ALC regarding the potential of the new technology. Also, the transition POC found that being kept up to date on development issues that were applicable to the plating shop was important.

In addition to the formal elements, the transition POC identified several informal elements listed in the questionnaire. Most important was the working relationship

established between WR-ALC and AL and between WR-ALC and the technical representative. The transition POC believes this relationship was possible because of the rapport and credibility that was established early in the program. AL was very proactive in seeking feedback from WR-ALC. This relationship was the foundation for a level of interaction where all parties willingly share information and ideas.

**Barriers: Using Organization Perspective.** The transition POC defined a successful transition as one in which the user is represented early and is funded sufficiently in order to develop and transition an effective technology. Under this definition, the transition POC considers the transition of the IVD process successful.

The transition POC identified two of the barriers discussed in the questionnaire that were present in the transition of the IVD process. First, technical risks posed a barrier prior to the start of phase three, since only 80 percent of WR-ALC's parts that were processed through the plating shop were identified as IVD applicable. However, as the technology was implemented into the plating shop, new techniques and processes were developed by plating shop employees that enabled 100 percent of the parts to use the IVD process.

Secondly, a diminishing budget for new technology has hindered the transition POC's ability to keep current on new technologies. Due to a lack of funds, key personnel are unable to attend trade shows and subscribe to technical publications. The current method of keeping up to date includes subscribing to free trade journals and relying on technology vendors who come to WR-ALC and demonstrate new technologies.

**Bridges: Using Organization Perspective.** The transition POC identified several bridges discussed in the questionnaire that aided in the transition of the IVD process. First, having the technology on site, at no cost to WR-ALC, enabled all employees who would eventually use the IVD equipment to be properly trained on the process. Secondly, the transition POC believes that the steps AL took to develop a strong lab-user relationship early in the program will pay dividends when future technologies are transferred. A summary of barriers and bridges found in the transition of the IVD aluminum process is provided in Table 4.5.

TABLE 4.5

SUMMARY OF BARRIERS AND BRIDGES TO TRANSITION OF  
THE IVD ALUMINUM PROCESS

<b><u>Barriers</u></b>	
<b>Technical</b> (U) Technical Risk	<b>Regulatory</b> (U) Diminishing budget
<b><u>Bridges</u></b>	
<b>General</b> (U) Developing lab-user partnerships and involving the user early	(U) Providing test facilities and support to potential technology users
(U) Identifying technology champion	(U) Technical ability of transition POC
<b>Formal</b> (U) Proper distribution of information	
<b>Informal</b> (U) Credibility of the parties involved	(U) Willingness to communicate ideas and information

A summary of all findings identified in the five environmental technology transition cases is provided in Table 4.6. This table presents a graphical representation of the key findings addressed in the following section.

TABLE 4.6  
SUMMARY OF FINDINGS FROM ENVIRONMENTAL  
TECHNOLOGY TRANSITION CASES

	Wright Laboratory		Armstrong Laboratory		
	Battery	HFC-125	ROST	Bioventing	IVD
<b>Technical Barriers</b>					
Technical risk	(U)	(U)	(D)		(U)
Schedule constraints		(D)			
<b>Regulatory Barriers</b>					
Diminishing budgets	(D, U)				(U)
Regulatory agency oversight		(D)	(D)	(D)	
<b>People Barriers</b>					
Lack of awareness of technology	(U)		(D)	(D, U)	
Rotation of military personnel		(D)			
Fear of leadership's ability		(D)			
Task-saturated personnel				(D)	
<b>Other Barriers</b>					
Difficulty in defining end-user			(D)	(D)	
<b>General Bridges</b>					
Newsletters, meetings, etc.	(D)				
Lab-user relationship	(D, U)	(D, U)	(D)	(D, U)	(U)
Strong leadership	(D)				
Strong external environment	(D)	(D, U)		(U)	
Identifying technology champion	(D, U)	(D, U)	(D)	(D)	(U)
Willingness to learn and explore	(D)				
Technical ability of transition POC	(D, U)	(D, U)	(D)	(D, U)	(U)
Providing test facilities/support			(D)	(D, U)	(U)
Recommendations of third-party			(D)	(D)	
Demonstrating technology to user			(D)	(U)	
Aggressive marketing effort				(U)	
Technology selection matrix				(U)	
Confidence in technology				(U)	
<b>Formal Bridges</b>					
Thorough documentation	(D)	(D)	(D)	(D, U)	
Establishment of transition project	(D)				
Proper distribution of information	(U)	(U)	(D)		(U)
<b>Informal Bridges</b>					
Communicating ideas/information	(D)	(D)			(U)
Credibility of parties	(D)			(D, U)	(U)
Reward mechanisms		(D)	(D)		



### **Key Findings: Barriers and Bridges**

With an understanding of the process and the barriers and bridges encountered in each of the previous five cases, coupled with the information provided in Table 4.6, comparisons and contrasts between the cases and the previous literature can now be made. These comparisons and contrasts will focus on addressing the research objectives.

**Unique to the Transition of Environmental Technologies.** While many barriers and bridges were identified as important to the transition of these environmental technologies, a revisiting of the literature review in Chapter Two indicates that only a few select barriers and bridges can be classified as unique to the transition of environmental technologies. Instead many of the key barriers and bridges are also present in the transition of general technologies.

With regards to barriers unique to the transition of environmental technologies, the halon replacement, ROST, and bioventing cases identify the difficulty of working under extreme oversight from environmental protection organizations as a barrier to the transition process. This regulatory agency oversight barrier is unique to environmental transition efforts because many environmental transition programs involve technologies developed to counter environmental regulations and policies that the user must comply with. With environmental technologies, there is also a need to *prove* to the regulatory agency that the technology will meet its requirements. This oversight and *proving* process is seldom the case with the development and transition efforts of general technologies. The regulatory risk encountered with the transition of general technologies focuses on

either a lack of specifications or a disconnect between existing specifications and the new technology.

The difficulty in clearly defining the end-user was identified as an additional barrier unique to the transition of environmental technologies. This barrier was identified in both the ROST and bioventing cases. With environmental technologies that are developed for operational-type end-users, there are many ways of classifying the technology recipient; individual installation, a group of bases in a similar geographical location, or MAJCOM level. This differs from the transition of general technologies in that most often general technologies are developed for major weapon systems. When the general technology is transferred, while the weapon system may eventually end up at multiple installations, the technology is transferred to the single SPO that manages the weapon system.

In addition to the barriers identified above, there is a single bridge that can be classified as unique to the transition of environmental technologies; the ability to demonstrate the technology to potential end-users. This bridge was a key factor in the success of the ROST and the bioventing process transition efforts. This practice is unique to environmental technologies because of the likelihood that the developed technology can be applied to many installations with the same general environmental need. This need to demonstrate the technology to many end-users is not found in the transition of general technologies due to the likelihood that the technology is to be applied to a single weapon system platform.

**Important to the Transition of Environmental Technologies.** In addition to the unique barriers and bridges, this section provides additional barriers and bridges that are

important to the successful transition of environmental technologies. Barriers and bridges found in this section include those that are not specific to the transition of environmental technologies.

First, as identified in all the transition cases with the exception of the bioventing case, technical risk presents a barrier to the transition process. In the maintenance-free battery, halon replacement, and IVD aluminum cases, technical risk was evidenced by concerns over integration of the new technology with existing weapon systems or manufacturing processes. Technical risk was a concern for the ROST system because of the uncertainties posed by the exploratory-type development effort.

Additionally, a lack of awareness of the new environmental technologies presented a barrier for several of the environmental transition cases. In the ROST and bioventing cases, this barrier can mostly be attributed to the need to educate essentially all Air Force installations about the new technologies being developed. This process requires time and resources, and includes the possibility that a potential end-user may not receive information about the environmental technology.

Finally, it is important to note that while Edwards' research indicates transitions pulled by the users were more likely to succeed than those pushed from the developing organization, the evidence provided in the case studies indicate otherwise. Of the five environmental technology transition cases studied, only the bioventing process was identified as a technology that was pulled by the user from the laboratory. The transition programs presented in the cases provide examples of technologies that are currently, or

are soon to be, successfully fielded with either a weapon system or an operational field organization.

In addition to these barriers, several additional bridges were identified as vital to increasing the likelihood for success when transitioning environmental technologies. Related to the bridge of demonstrating the technology to potential end-users is the bridge of providing test and demonstration facilities to the end-user. By bringing the technology to individual installations and providing test facilities and equipment, as was the case with the bioventing, IVD aluminum, and the ROST technologies, the laboratory is better able to provide assurance to both the end-user and the regulators that the technology will operate in an acceptable manner.

Equally important to providing test and demonstration facilities, securing third-party recommendations must be considered an additional bridge vital to a successful environmental transition effort. In the case of environmental technologies, the recommendation of a regulatory agency is key. Combined with the developer's ability to demonstrate the technology, using test and demonstration facilities at the installation site, a third-party recommendation provides the end-user with a complete sense of confidence that the technology will work correctly and will solve their problem satisfactorily in the eyes of the regulators.

An additional bridge identified in all five of the case studies was the technical competence of the transition POCs involved in the transition of the environmental technologies. Many of the transition POCs classified their positions as combining program management and engineering skills. An understanding of the environmental

technologies being transitioned is developed from these engineering skills. This finding is in agreement with Gummere's research which revealed that technology transitions are done best when completed between engineers.

The impact of a strong external environment was also identified as a positive factor in the transition of these environmental technologies. In the maintenance-free battery case, it was noted that the technology likely would have not completed the development phase if not for the additional funding provided due to the environmental benefits of the program. In other cases, program visibility was increased due to the attention environmental issues have received recently.

The importance of identifying a technology champion was identified as a bridge present in all five case studies as well as previous literature discussed in Chapter Two. In several cases the technology champion was found in the developing organization, while in other cases the champion was present in the using organization. Regardless of this difference, all five case studies describe the technology champion as a key element in the marketing and funding processes; both key to the success of the transition of the environmental technology.

The credibility of the parties involved in the transition and the development of a positive lab-user relationship are related bridges identified in several of the environmental transition cases. They are related in such a way that without trustworthy, credible transition personnel within both the development organization and the using organization, it is impossible to establish and maintain a positive working relationship.

Finally, thorough documentation, proper distribution of information, and communicating ideas and information are several additional related bridges important to the transition of environmental technologies. These three bridges also add to the positive effect that a good working relationship between the lab and the user can have on a transition program. Documentation, distribution, and communication all improve the process of educating new end-users, and improve the program review process by keeping current and accurate records of the development and transition efforts. A summary of barriers and bridges, both unique and important, to the transition of environmental technologies is found in Table 4.7.

**End-User: SPO Versus Operational Field Organization.** Of the five cases studied, the transition of the maintenance-free battery to the Joint STARS program and the transition of HFC-125 to the F-22 program are considered transitions to major weapon systems. The remaining cases (ROST, bioventing, and IVD aluminum) are considered transitions to operational field organizations.

There were several key differences between the transition of environmental technologies to a major weapon system and the transition to an operational field organizational. First, and most obvious concern the contrasts between the end-users. As previously discussed, the perception of those involved with the process of transitioning to operational level organizations, is that the process could be simplified if the user was as clearly defined as that of a major weapon system. In both case studies addressing major weapon systems, the technology was transitioned from the laboratory to a single end-user. In the ROST system and bioventing case studies, the potential end-user base consists of

nearly any operational installation. The IVD aluminum end-user base includes all Air Force ALCs, with the exception of the San Antonio ALC.

TABLE 4.7

SUMMARY OF BARRIERS AND BRIDGES, UNIQUE AND IMPORTANT, TO  
TRANSITION OF ENVIRONMENTAL TECHNOLOGIES

<b><u>Barriers and Bridges Unique to Environmental Technologies</u></b>	
<b>Barriers</b>	
Regulatory agency oversight	Difficulty in clearly defining the end-user
<b>Bridges</b>	
Demonstrating the technology to potential end-users	
<b><u>Barriers and Bridges Important to Environmental Technologies</u></b>	
<b>Barriers</b>	
Technical risks	Lack of awareness of new technology
<b>Bridges</b>	
Providing test and demonstration facilities to the end-user	Technical competence of the transition POCs
Identifying a technology champion	Securing third-party recommendations
Strong external environment	Communicating ideas and information between parties
Credibility of parties involved	Thorough documentation
Proper distribution of information	Developing lab-user partnerships

In addition to the differences between the end-users, there is a difference in focus between the laboratory that is transitioning to the weapon system and the laboratory that is transitioning to the operational field organization. Within WL, how to improve a

weapon system is the focus of a majority of the technologies developed at that laboratory. In the maintenance-free battery case, even though the technology had strong environmental benefits, the focus of the development effort was how to improve the performance of the aircraft. The aircraft battery development shop is focused on developing batteries that improve performance, and if there are environmental benefits to be realized, then that is an additional plus. This is not to say that the transition POCs in WL are not knowledgeable about the environmental implications of the technology being transitioned, rather, that their focus is on improving the operational capability of the weapon system.

This differs from the focus of AL. AL develops environmental technologies for the sole purpose of solving environmental problems in the field. The transition POCs within AL are more focused on the environmental implications of the technologies being developed, and are therefore, more aware of the difficulties involved with the barriers and bridges involved with transitioning them to the field. Again, this difference is pointed out not to deem one organization as better than the other, only to highlight a difference in focus between the two laboratories.

The difference in the definition of a successful transition effort is the final difference identified in this research effort. While the end-user is the primary focus of all the definitions of success in the five cases, there is a difference in to what extent the user receives a product or process. In the weapon system focused cases, the development and transition of a product or process to the end-user is mentioned as a measure of success. This differs from the operationally-focused end-user cases, where the measure of success



is generally the development of a technology, with less of an emphasis on the actual transition to the end-user. Further analysis indicates this difference is due to the differences in the end-users discussed previously. With the weapon system transition efforts, the laboratory is able to focus on a single end-user, the SPO. In contrast, the laboratory developing environmental technologies for operational end-users is unable to narrow their focus as much where there may be multiple end-users. This difference effects AL in that the goal is to develop a technology, then make it available to all end-users that have a requirement for the technology.

Identifying and discussing the similarities between the transition processes is as equally important as identifying and discussing the differences. First, in all but one case, IVD aluminum, either the developing organization or the using organization had developed some type of plan to aid in the transition of the environmental technology. The contents and depth of the plan varies between the transition efforts. However, it is evidenced by the case studies that the development and implementation of the plan was a vital factor in establishing time schedules, identifying potential users, and initiating a thorough documentation effort.

Finally, it was hypothesized in Chapter Three that the requirements generation process for weapon systems procurement was more stringent than for operations-level environmental organizations. Analysis of the cases indicate this is not the case; at least in the transition of environmental technologies. Two aspects of the transition cases support this finding. First, of the five cases studied, only the bioventing process was pulled from the laboratory by the user, the remaining technologies were pushed from the laboratory.

Secondly, no Mission Need Statement, or similar document, was used to initiate a research and development program in any of the transition cases. This does not mean a requirements general system was not used at all, only that it was a more informal process. A summary of differences and similarities found in the transition of environmental technologies from laboratory to weapon systems versus laboratory to operational field organization is found in Table 4.8.

TABLE 4.8

SUMMARY OF DIFFERENCES AND SIMILARITIES BETWEEN WEAPON SYSTEMS AND OPERATIONAL FIELD ORGANIZATIONS

<u>Differences</u>	
Contrasts between the end-users	Differences in the focus of the laboratories
Differences in defining a successful environmental transition effort.	
<u>Similarities</u>	
Use of a transition plan	Informal requirements generation process

Summary

The purpose of this chapter was to present data gathered in support of the case study methodology described in Chapter Three and use this data to formulate responses to the research objectives. Chapter Five will now focus on addressing the managerial challenges associated with the findings presented in this chapter, and address potential areas for further research.

## **V. Conclusions and Recommendations**

### **Introduction**

Based on the conclusions presented in Chapter Four, the purpose of this chapter is to discuss the managerial challenges these findings present and offer recommendations to aid in dissolving barriers and increasing awareness of bridges to the transition of environmental technologies. Following the discussion on managerial challenges, a section is devoted to providing suggestions for further research in this area. Next, Air Force environmental technology and organizational structure issues are presented. Finally, the chapter concludes with an overall summary of this research effort.

### **Managerial Challenges**

The conclusions formed in Chapter Four indicate that when transitioning environmental technologies there exists barriers, both unique and important, to the transition of these types of technologies. The halon replacement, ROST, and bioventing cases identified the environmentally unique difficulties of managing an environmental development and transition program within the bounds of keen oversight provided by local, state, and federal environmental protection agencies. In addition, analysis of the ROST and bioventing cases highlight the barriers present when trying to clearly identify the end-user of an environmental technology.

Additionally, technical risk and a lack of awareness of the new environmental technology were identified as environmental barriers that, while not unique to the

transition of environmental technologies, still need to be identified when transitioning these type of technologies. Regarding these two barriers, the manager of an environmental transition effort is challenged to ensure technical risk issues concerning integration and uncertainty, and end-user awareness issues are addressed early in the technology development program.

### **Recommendations for Change**

With an understanding of the differences and the specific barriers encountered when transitioning environmental technologies, managers can better plan and execute environmental technology transition programs. The following points provide several recommendations for improving the environmental technology transition process based on the results of this research effort.

First, when fiscally and logistically possible, environmental technologies focused on the operational field organization should be demonstrated to as many potential end-users as possible. With installations covering such a diverse array of geographical locations, it is important to provide the end-user with assurance that the technology can meet their needs in a way that is satisfactory to the regulators in their region. As discussed in the bioventing case, testing and demonstrations should not be looked at as R&D efforts; rather they are opportunities to market the technology.

Additionally, by providing test and demonstration facilities, the end-user and the regulator are given an opportunity to see the technology operate in an actual operational environment, instead of a laboratory setting. By incorporating this type of testing and

demonstration medium, the regulatory agency is provided with unquestionable evidence as to the validity of the environmental technology in question. To close this loop, it is imperative to seek the recommendation and approval of the regulatory agency.

There are several human aspects that when implemented can also improve the likelihood of success in the transition of environmental technologies. As identified in all five case studies, key transition POCs need to be familiar with the technology being transitioned. When permissible, involve the transition POC in the development phase of the program. Also, early in the development effort, a champion for the environmental technology needs to be identified. This individual need not be directly involved with the development effort. However, he must be able to present the technology to potential end-users, understand and help define their requirements, and know how to seek funding for the development and transition efforts. Finally, establish a positive, credible working relationship between the laboratory and the end-user. Thorough documentation, communicating this information in a timely manner, and exchanging ideas present opportunities to maintain this working relationship.

### **Recommendations for Future Research**

Chapter Two points out that little research exists that examines the transition of environmental technologies. Therefore, a case study methodology was developed for this research project that successfully, for five cases described the transition process and the experiences encountered during those transition efforts. However, it was this case study

methodology that also introduced several areas that still pose many questions. It is these areas that are recommended for further research.

**Technology Transfer.** These five case studies all focused on the process of transitioning technology from a laboratory environment to a user within the Air Force. While it is possible that many of the findings of this research effort would be found in a study of transfer efforts, there are peculiarities that occur when dealing with organizations in the private sector. It is these peculiarities that would make an excellent focus for future research. It is quite possible the research design would use the same methodology, with the limited information available on the transfer of environmental technologies.

**Individual Case Study.** Again, due to the lack of previous research, it was determined that studying several cases would lead to results that could be compared and contrasted with results found in the other cases. Additional research could focus on one specific case study that would analyze the transition from development to user implementation of a single environmental technology. By focusing on a single case, the researcher can increase the depth to which the transfer effort is analyzed. More personnel involved with the transition process could be interviewed using a survey methodology, allowing for a more quantitative research approach.

**Development of Environmental Technology Transition Guide.** This research effort has taken the initial step in identifying some of the peculiarities encountered when transitioning environmental technologies. Future research could incorporate findings from previous research on environmental technology transition and develop a guide to be used as a tool to increase the likelihood of transition success.

**Measures of Success.** Results from this research indicate that when asked, no two people involved with the transition of environmental technologies defined a successful transition the same way. Additional research should build on the findings of previous research in this field of success measures and develop a methodology or algorithm for measuring and tracking success in the transition of environmental technologies.

**Role of Private Industry.** As mentioned previously, this research effort focused on environmental technologies developed in government laboratories, with limited private industry involvement. As identified by AFCEE and HSC, in many cases private industry is leading the race in the development of new environmental technologies. Two potential research efforts are derived from this situation. First, analyze the impact of federal laboratories essentially competing with private industry. Secondly, a research effort that compares and contrasts the transition/transfer processes of AL with a private sector R&D firm.

**The External Environment.** Results of this research indicate that the external environment was a factor in the transition of environmental technologies. Most interview respondents defined the external environment as the increased awareness of environmental issues. A future research project could analyze what it is that makes up this external environment. Is it due to the publicity that environmental issues have received in the past decade; is it an increase in pressure from senior DoD leadership to solve environmental problems; or is it an increase in the oversight of environmental protection agencies and the strict regulations they impose on the DoD? Finally, is the external environment factor a barrier or a bridge to a successful transition of environmental technologies?

## Air Force Environmental Technology Policy and Organizational Structure

This section presents additional information gathered from discussions with decision makers involved in the transition of AL-developed environmental technologies. These comments offer a *corporate* view of the transition process and present the perspectives of both the developing and using organizations.

There is a perception among the decision makers that the transition process developed by AFMC, to be applied by all laboratories, is focused on meeting the needs of major weapon systems as opposed to meeting the needs of base-level users. The belief among these decision makers is that the tools developed by AFMC to improve the technology transition process are difficult to apply to the transition of environmental technologies since the perception is that these tools are guides to be used in the transition of general technologies to major weapon systems.

In addition, discussion focused on the current disconnect in the organizational structure of AFMC and the civil engineering community. In the past, the Environics Directorate of AL (AL/EQ) was an asset of the civil engineering community as part of the Air Force Civil Engineering and Services Agency (AFCESA). Currently, AL/EQ is an asset of AFMC within the research and development laboratory structure. This disconnect is evidenced by the fact that AFCEE is an organization within the civil engineering community, while AL and HSC are AFMC organizations.

The decision makers also identified a disconnect in responsibilities for the transition of technologies from not only AL, but from other Federal Laboratories and private industry. They believe this is due in part to the programmatic structure the organizations in question



operate in, again referring to the fact that AFCEE works for the Civil Engineer of the Air Force, while AL and HSC are AFMC organizations.

Also, there is concern among the decision makers that private industry develops new environmental technologies faster than Federal Laboratories, including AL. It is their belief this situation exists due in large part that there are numerous companies that conduct environmental R&D in addition to the efforts being conducted at AL. This differs in the R&D of technologies for major weapon systems which usually have Federal Laboratories as their only means of developing a required technology.

Finally, there is concern regarding the current Technology Planning Integrated Product Team (TPIPT) process and the role this process plays in the development and transition of environmental technologies. The Environmental, Safety, and Occupational Health (ESOH) TPIPT was created by AFMC as one of 21 TPIPTs within the Command. The goal of these TPIPTs is to "integrate information from all of the stakeholders, provide a forum to understand AF mission area requirements, and develop solutions and identify technology needs" (1:2-2). As part of this effort to identify the environmental needs of the Air Force, the ESOH TPIPT distributes an annual survey to every installation asking that they prioritize their environmental deficiencies. These individual lists are in turn prioritized by the ESOH TPIPT. The problem is that the ESOH TPIPT is minimally funded, and therefore must sponsor programs where funds already are programmed. For example, an environmental technology deficiency ranked not very highly could become the top priority if it has sufficient funds to be developed and transitioned.

These points provide many additional opportunities for future research. Areas of interest include researching the benefits associated with re-establishing Armstrong Laboratory's Environics Directorate (AL/EQ) under the Air Force Civil Engineering function. Research should also focus on establishing clear responsibilities for all parties involved in the transition of environmental technologies, including the ESOH TPIPT.

### **Thesis Summary**

This research effort identified the transition of environmental technologies from laboratories to DoD users as a significant issue, important to the successful remediation of past and the prevention of future of environmental mistakes. Surprisingly, even though environmental issues are a concern of most DoD and private organizations, previous research was limited in analyzing the process of transitioning environmental technologies.

The five case studies presented here provide a detailed investigation into the environmental technology transition process, and the barriers and bridges encountered during this process. Using the review of previous literature as a foundation for developing research objectives, the interview process and follow-on analysis allowed for the identification of key barriers and bridges present in the transition of these five technologies. Based on this analysis, key findings that supported the research objectives were presented, and a discussion of recommendations for change was offered for use by organizations involved with the development and transition of environmental technologies.

Finally, in addition to answering the research objectives, this research effort also introduced questions that were left unanswered. Potential future research would focus on

studying the process of transferring environmental technologies to private industry; conducting further research on a specific environmental technology; developing an environmental technology transition guide; researching and developing measures of success for environmental technologies; analyzing the effort of private industry on the development and transition process; and analyzing the effects and composition of the external environment. It is these future research efforts that in turn stimulate additional questions, which further enhance our understanding of the transition of environmental technologies.

## Appendix A: Interview Questions

### PERSONNEL BACKGROUND INFORMATION

1. How long have you been employed with the government?
2. How long have you been employed with this organization?
3. a) How many years (months) of technology transition experience do you have with this organization (29:66)?  
  
b) Outside of this organization?
4. a) What is your role in the transition process for the technology being discussed (29:66)?  
  
b) How many years (months) in this position?  
  
c) How familiar are you with the technology involved (17:28)?  
  
d) How long (years, months) have you been involved with this specific transition?  
  
e) Have you been involved with other transition projects in this organization?
5. a) Please provide an organizational diagram, and indicate the office you work for (18:96-97).  
  
b) Besides this technology transition project, what other responsibilities do you have within the organization (17:30)?
6. Would you classify your position as that of a scientist, an engineer, or a manager/administrator (17:30; 18:96-97)?

### TECHNICAL PUSH VERSUS MARKET PULL

1. Was the technology developed and “pushed” into a suitable application, or was the technology developed and “pulled” into an application to meet an existing need (17; 14:46)?
2. a) How was the potential user identified (14:46)?  
  
b) Who identified the potential user?  
  
c) How was the interface established?
3. Organization and location of identified user (if multiple users, provide information for all that apply) (25:9)?
4. a) Was a Mission Need Statement (MNS) generated for this project?  
  
b) If yes, who initiated the MNS, the user or the developer?  
  
c) If no, how was the technological need/availability identified?

## TRANSITION PROCESS IMPLEMENTATION

1. a) Was a formal strategy developed and implemented to guide the transition of the technology (11:69-71; 17:31)?  
  
b) If yes, explain the elements of the plan and specific actions accomplished.  
  
c) If no, why was no formal plan initiated?
2. To what extent were the following formal elements present in the transition process?  
Which of these elements were the most important to the transition process (11:69-71)?  
  
a) Specific individual (champion) identified to lead the transition effort.  
  
b) Specific project established to track the effort.  
  
c) Documentation of the transition.  
  
d) Proper distribution of information to appropriate players in the transition.  
  
e) Other elements that could be considered "formal" in nature.
3. To what extent were the following informal elements present in the transition process?  
Which of these elements were the most important to the transition process (11:72-77)?  
  
a) Working relationship established between the laboratory and the user.  
  
b) Credibility (trustworthy in nature) of parties involved.  
  
c) Willingness of the parties to communicate information and ideas.  
  
d) Reward mechanisms.  
  
e) Other elements that could be considered "informal" in nature.

## LESSONS LEARNED: BRIDGES AND BARRIERS

1. What is your definition of a successful technology transition? Using your definition with this case, was this transition successful?
2. To what extent were the following barriers present in the transition process, what was the impact on the transition process, was it overcome, and how (17:27-28; 5:17; 4:42-43; 29:66; 17:28; 31:34; 18:101; 25:7, 31; 20:248-249)?
  - a) Technical risk.
  - b) Lack of a defined requirement.
  - c) Lack of operational test data.
  - d) Risk aversion (user or laboratory).
  - e) Lack of technical orders provided for the user.
  - f) Long procurement lead times.
  - g) Lack of regulations defining the use of the technology.
  - h) Diminishing research and development budget.
  - I) Lack of awareness of the new technology (user of laboratory).
  - j) Fears about leadership's ability to handle the new technology.
  - k) Additional barriers.

3. What barriers discussed previously do you think are specific to the transition of environmental technology versus non-environmental technology?
4. To what extent were the following bridges present in the transition process and what was the impact on the transition process (28:9-11; 6:33; 30:36-37; 17:31; 34:26-27)?
  - a) Tracking and measurement of transition progress and effectiveness.
  - b) Providing testing facilities and support to technology users.
  - c) Newsletters, meetings, training sessions, consulting, and advertising.
  - d) Ability to seek out key players (champions).
  - e) Recommendations of third-party organizations.
  - f) Tangible value to the user in the technology being transitioned.
  - g) Developing laboratory-user partnerships and involving the user early.
  - h) Strong leadership.
  - I) Strong external environment.
  - j) A "spirit" and willingness to explore and learn.
  - k) Additional bridges.
5. What bridges discussed previously do you think are specific to the transition of environmental technology versus non-environmental technology?
6. What additional lessons can be learned from this transition?



## Bibliography

1. Air Force Material Command, Department of the Air Force. Guide to the Technology Master Process. Wright-Patterson AFB OH: HQ AFMC, 24 June 1995.
2. Air Force Material Command, Department of the Air Force. Technology Transition Planning. AFMC Instruction 61-102. Wright-Patterson AFB OH: HQ AFMC, 13 March 1995.
3. Baker, Nancy C. "From Swords to Plowshares: Military Provides Springboard for New Cleanup Methods," Environmental Technology: 27-32 (April 1993).
4. Baron, Seymour. "Overcoming the Barriers to Technology Transfer," Research Technology Management, 33: 38-43 (January-February 1990).
5. Carr, Robert K. "Doing Technology Transfer in Federal Laboratories (Part 1)," Technology Transfer, 17: 8-23 (Spring-Summer 1992).
6. Carr, Robert K. "Menu of Best Practices in Technology Transfer (Part 2)," Technology Transfer, 17: 24-33 (Spring-Summer 1992).
7. Charness, Michael R., Gordon M. Davidson, Eric M. Drattell, and Ronald B. Vogt. "A Brave New World for Federal Facilities Contractors," Environmental Management Review, 35: 29-52 (First Quarter 1995).
8. Connor, Mark J. "What is the Federal Facility Compliance Act All About and What Are the Implications." Unpublished report. Executive Enterprises, New York NY, October 1994.
9. Cooper, Donald R. and C. William Emory. Business Research Methods. Chicago: Richard D. Irwin Inc., 1995.
10. Corey, E. Raymond. MBA Field Studies: A Guide for Students and Faculty. Boston: Harvard Business School Publishing Division, 1990.
11. Creighton, J.W., J.A. Jolly, and T.A. Buckles. "The Manager's Role in Technology Transfer," Technology Transfer, 10: 65-81 (1985).
12. Dane, Francis C. Research Methods. Pacific Grove CA: Brooks/Cole Publishing Company, 1990.

13. Defense Systems Management College, Department of Defense. Introduction to Defense Acquisition Management. Washington: U.S. Government Printing Office, March 1993.
14. Edwards, Robert L. "The Industrial Revitalization Forum Program: Successful Industry/University Cooperation," Technology Transfer, 19: 43-46 (August 1994).
15. ESOH IPT. "Technology Transition Path Determination Process." Unpublished report. Brooks AFB TX, February 1996.
16. Franza, Richard M. and Brett T. Smith. "The Technology Transfer Process: A Case Study of the National Aero-Space Plane (NASP) Program," Technology Transfer Society Technology Transfer Proceedings, 21st: 73-82 (July 1996).
17. Guilfoos, Stephen J. "Bashing the Technology Insertion Barriers," Air Force Journal of Logistics: 27-32 (Spring 1989).
18. Gummere, Robert J. The Technology Challenge of the Advanced Tactical Fighter: A Study of the Technology Transition Process. MS thesis, AFIT/GSM/LSM/89S-13. School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1989 (AD-A216109).
19. HQ AFMC/CEV. "Air Force Material Command: Environmental Management." Unpublished briefing charts. Wright-Patterson AFB OH, 1995.
20. Majchrzak, Ann. The Human Side of Factory Automation. San Francisco: Jassey-Bass Inc., 1988.
21. National Science and Technology Council. Technology for a Sustainable Future: A Framework for Action. Washington: U.S. Government Printing Office, 1994.
22. National Science and Technology Council. Bridge to a Sustainable Future. Washington: U.S. Government Printing Office, April 1995.
23. Sharfman, Mark. "Regulation, Business, and Sustainable Development." Unpublished Research Proposal. Norman OK: University of Oklahoma College of Business Administration, 1995.
24. Skinner, Kevin. Chief, Application Insertion Integration Team, Technology Transition Office, Air Force Material Command, Wright-Patterson AFB OH. Personal Interview. 18 Jan 96.

25. Smilor, R.W. and D.V. Gibson. "Technology Transfer in Multi-Organizational Environments: The Case of R&D Consortia," IEEE Transactions on Engineering Management, 10: 3-13 (February 1991).
26. Smith, Brett T. The Process Of Technology Transfer: A Case Study of the National Aero-Space Plane Program. MS thesis, AFIT/GSM/LAS/95S-8. School of Logistics and Acquisition Management, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1995 (AD-A300506).
27. Smith, Bruce. BRAC Program Analyst, U.S. Army Reserve Command, Atlanta GA. Personal Correspondence. 15 January 1996.
28. Souder, Wm. E., Ahmed S. Nasher, and Venatesh Padmanabhan. "A Guide to the Best Technology Transfer Practices," Technology Transfer, 15: 5-14 (Winter-Spring 1990).
29. Spann, Mary S., Mel Adams, and Wm. E. Souder. "Improving Federal Technology Commercialization: Some Recommendations From a Field Study," Technology Transfer, 18: 63-73 (Summer-Fall 1993).
30. Trott, P., M. Cordey-Hayes, and R.A.F Seaton. "Inward Technology Transfer as an Interactive Process," Technovation, 15: 25-42 (1995).
31. United States General Accounting Office. Military Bases: Environmental Impact at Closing Installations. Report GAO/NSIAD-95-70. Washington: U.S. Government Printing Office, 23 February 1995.
32. U.S. Army Corps of Engineers, Department of the Army. Corps of Engineers Technology Adoption Process (CETAP) Study. Report AD-A275-801. Washington: USACE, July 1993.
33. West, William K. An Exploration of Technology Transfer Control: A Case Study of Wright Laboratory. MS thesis, AFIT/GSM/LAS/94D-1. School of Logistics and Acquisition Management, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, December 1994 (AD-A288876).
34. Wood, O. Lew and Errol P. EerNisse. "Technology Transfer to the Private Sector from a Federal Laboratory," IEEE Engineering Management Review, 20: 23-28 (Spring 1992).
35. Yin, Robert K. Case Study Research Design and Methods. Newbury Park CA: Sage Publications Inc., 1989.

### Vita

Captain Mike Greiner graduated in 1991 from the University of Portland with a Bachelor of Science degree in Physics and was commissioned in the USAF through the Reserve Officers Training Corps (ROTC) where he was a Distinguished Graduate. He served his first tour of duty at Nellis AFB, NV with the 554th Range Squadron where he was an Environmental Project Manager for the Nellis Range Complex. In May 1995, Captain Greiner was selected to attend the Air Force Institute of Technology Graduate Program for Cost Analysis. He will graduate in September 1996, and will be assigned to the Electronic Systems Center, Hanscom AFB, MA following graduation.

Permanent Address:  
15850 SE Grant St.  
Portland, OR 97233

**REPORT DOCUMENTATION PAGE**Form Approved  
OMB No. 074-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of the collection of information, including suggestions for reducing this burden to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503

**1. AGENCY USE ONLY (Leave blank)****2. REPORT DATE**  
September 1996**3. REPORT TYPE AND DATES COVERED**  
Master's Thesis**4. TITLE AND SUBTITLE**AN EXPLORATION OF ENVIRONMENTAL TECHNOLOGY TRANSITION  
FROM THE LABORATORY TO THE FIELD**5. FUNDING NUMBERS****6. AUTHOR(S)**

Michael A. Greiner, Captain, USAF

**7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S)**Air Force Institute of Technology  
2750 P Street  
WPAFB OH 45433-7765**8. PERFORMING ORGANIZATION  
REPORT NUMBER**

AFIT/GCA/LAS/96S-7

**9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)**Armstrong Laboratory/Enviro-nics Directorate  
Major John Gee  
Tyndall AFB FL 32403-5323**10. SPONSORING / MONITORING  
AGENCY REPORT NUMBER****11. SUPPLEMENTARY NOTES****12a. DISTRIBUTION / AVAILABILITY STATEMENT**

Approved for public release; distribution unlimited

**12b. DISTRIBUTION CODE****13. ABSTRACT (Maximum 200 Words)**

Environmental policy, social factors, individual behavior, and environmental technologies are key factors in improving the current condition of the environment. The Department of Defense (DoD) is not immune to these aspects, as its actions have and will continue to impact the environment in which they conduct operations.

The objective of this research is to analyze the environmental technology aspect of improving environmental conditions. Of particular interest, what barriers and bridges are encountered when an Air Force laboratory transitions environmental technologies to an end-user: operational field organization or major weapon system. The research employs a case study methodology to analyze five environmental technology transition efforts within the Air Force.

Several key findings identify barriers and bridges specific to the transition of environmental technologies. They include: oversight of environmental protection agencies, the difficulty in clearly defining the end-user, and the need to demonstrate environmental technologies to potential end-users. Further analysis of the case studies indicate that many of the barriers and bridges encountered in the transition of environmental technologies are also encountered in the transition of general technologies. In addition, the researcher provides recommendations for change, and offers future opportunities for research in the area of environmental technology transition.

**14. SUBJECT TERMS**Technology Transition, Technology Transfer, Environment, Department of Defense,  
Environmental Technology**15. NUMBER OF PAGES**

120

**16. PRICE CODE****17. SECURITY CLASSIFICATION  
OF REPORT**

Unclassified

**18. SECURITY CLASSIFICATION  
OF THIS PAGE**

Unclassified

**19. SECURITY CLASSIFICATION  
OF ABSTRACT**

Unclassified

**20. LIMITATION OF ABSTRACT**  
UL

## AFIT RESEARCH ASSESSMENT

The purpose of this questionnaire is to determine the potential for current and future applications of AFIT thesis research. **Please return completed questionnaire** to: AIR FORCE INSTITUTE OF TECHNOLOGY/LAC, 2950 P STREET, WRIGHT-PATTERSON AFB OH 45433-7765. Your response is **important**. Thank you.

1. Did this research contribute to a current research project?      a. Yes      b. No
  
2. Do you believe this research topic is significant enough that it would have been researched (or contracted) by your organization or another agency if AFIT had not researched it?  
a. Yes      b. No
  
3. **Please estimate** what this research would have cost in terms of manpower and dollars if it had been accomplished under contract or if it had been done in-house.

Man Years \_\_\_\_\_ \$ \_\_\_\_\_

4. Whether or not you were able to establish an equivalent value for this research (in Question 3), what is your estimate of its significance?

a. Highly      b. Significant      c. Slightly      d. Of No  
Significant      Significant      Significance

5. Comments (Please feel free to use a separate sheet for more detailed answers and include it with this form):

\_\_\_\_\_  
Name and Grade

\_\_\_\_\_  
Organization

\_\_\_\_\_  
Position or Title

\_\_\_\_\_  
Address